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Section G
GEO-SCIENCES

Bull. Res. Counc. of Israel. G. Geo-Sciences

Page

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THE GEOLOGY OF THE CENTRAL JORDAN VALLEY

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ABSTRACT

The geology of the western rim of the central Jordan Valley (South of Kinnereth) is given. The area is built of sedimentary and volcanic rocks of Neogene and Quaternary age. The sedimentary sequence consists of a series of rocks developed in an inland basin. Shallow-marine to brackwater series, representing an ingression of a Neogene sea into a slowly subsiding depression, is topped by gypsum and followed by freshwater sediments. An intense volcanism was active during this period. Basic lava-sheets and pyroclastics form the base of the exposed formations and are intermixed with the sediments throughout the whole sequence. No dykes were found. The Neogene sedimentation and volcanism are closed by a regional basalt-outflow (cover or plateau-basalt), the source of the latter being outside the area, presumably in the west and southwest. The main faulting phase sets in shortly after the basalt outflows. Most of the faults are normal en-échelon faults arranged in longitudinal rows. They are interpreted as western border-faults antithetical to a main deep-seated eastern fault. Stratigraphical correlation of inland sediments inside and outside the area is attempted.

INTRODUCTION

The Jordan Valley has attracted the attention of geologists since the middle of the last century. From von Buch (1839), Lartet (1869), Fraas (1867) and Hull (1886) to Willis (1928) and others, various hypotheses on the structure and evolution of this valley have been proposed.

Blanckenhorn and Oppenheim (1927) investigated the fauna of the lacustrine–fluviatile formations and compared it with the fauna of Middle Eastern and East European inland basins. Detailed stratigraphical and structural analysis, as well as palaeogeographical synthesis of the Central Jordan Valley were given for the first time by Picard (1932, 1934, 1934a). Bentor (1946) described the geology of the area from W. Fajjas to Tiberias where continental Neogene formations ("red series"), which were not found farther South, are exposed. The relations between these continental sediments and Neogene basalts were described.

The present work, presented in Hebrew in 1956 as a thesis for the M. Sc. degree of the Hebrew University, is the result of field investigations started in December 1954. Many problems remain unsolved, and further investigations are in progress.

LOCATION AND MAIN MORPHOLOGICAL FEATURES

The investigated area extends in a narrow strip along the western part of the Jordan

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Valley, from W. Fajjas in the north to W. Ish-she in the south, between grid-line E198 in the west and the Jordan River in the east.

Three different morphological units, running in narrow N–S strips, can be distinguished:

1. *The escarpment* in the west, sloping downwards from the Sirin and Belvoir plateaux, its highest point being at + 367.8 m (19893/23118), with an average slope to the east of 1:3 or 18°. To the west, the Sirin plateau slopes gently (average 4°) to the WSW. W. Birrah, coming from the west, divides this plateau in two more or less equal parts.

2. *The foothills*, forming a belt 1–3 km wide, descend gradually and continuously from el. + 100 m in the west to the valley floor (— 200 m to — 250 m) in the east, the average total slope being 1:10 ($5\frac{1}{2}$°). At one point, however, between Menahamiya and Gesher, this gradual descent is disturbed. This is Tel-esh-Shahra, a conspicuous morphological point, rising above its surroundings to el. — 81.2 m, as an outpost facing east.

3. *The valley-floor**— built of terraces at different levels, the lowest point in our area being — 270 m.

STRATIGRAPHY

The area is built of sedimentary and volcanic rocks.

Sedimentary rocks

1. *The brackish lagoonal series* (*y*)

The oldest sedimentary formation exposed in the area is the brackish lagoonal or "yellow" series, called Tonmergel by Picard (1932). Covering an area of about 10 km^2 in small outcrops in the North and in larger ones in the South, its maximum measured thickness is 200 m. In the south (Belvoir-block) this series is underlain by the lower volcanic series, whereas in the north its base is not exposed.

The brackish lagoonal series is composed mostly of soft sediments; mostly marl and dark clays, but also of some thin chalk beds, dolomite and limestone, the last being sometimes bituminous. The sporadic bituminous outcrops are characteristic of the typical lagoonal conditions, and therefore, syngenetic.

Bedding is usually thin to very thin. No important lateral changes were observed within the area. The dominant weathering colour of the series is yellow to brownish-yellow. Being mostly brittle and soft, the rocks are usually covered by scree, and detailed sectioning could not be done.

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* Since the present survey is concerned mainly with the structural evolution of the area, little attention was paid to the younger Quaternary horizontal formations (Lisan, etc.). The stratigraphy and prehistory of the last were studied in the past (*Picard*, *Stekelis*). For a thorough geomorphological study of the terraces the extension of the investigated area to its eastern rim is indispensable.

The following are the descriptions of some of the typical outcrops:

Loc. 20148/22578, *el.* – 125 m, *W. Idma near Menahamiya–Gesher road.* Exposed thickness: 6 m.

Clay — marly and silty, dense, brown, slightly pyritic.
Marl — clayey, slightly silty, light-brown.
Marl — clayey, yellowish-brown; laminated; spheroidal weathering.
Marl — clayey, yellowish-brown, with some quartz crystals 0.1–0.4 mm long transparent idiomorphic-prismatic, authigenic; Neogene fauna. Alternating bands of marl and clay, grey to light brown; laminated.
Limestone — chalky and silty, soft, salty, brown; in beds of 10 cm.
Chalk — marly, silty, limonitic, light-brown.
Marl — clayey, slightly silty, light-brown to grey, laminated and fissile.

Loc. 20178/22534, *el.* – 170 m. Exposed thickness: 1 m.

Chalk — slightly marly and silty, light-brown; Neogene microfauna.
Clay — compact, dark-brown, with some small transparent quartz-grains, some gypsum and plant remains.

Loc. 20146/22782, *el.* – 50 m, *W. et-Tuleh.*

Chalk — yellowish, laminated.

The lithologic character of these rocks points to a quiet sedimentation, shallow, monotonous, brackish lagoonal environment (dark organic clay, pyritic mud).

The sedimentary basin of this series extended all over the investigated area. Its eastern boundaries are unknown. In the north, the correlation with corresponding sediments is hypothetical (see p. 85). To the west, the series passes into the Yizreel (Esdraelon) Valley. The stratigraphic and facial correlation between the brackwater series in the eastern Galilee basin and the sediments of the marine Neogene in the Yizreel Valley still awaits exact determination. In the south, in the Beit-Shan Valley, the brackwater series is concealed under the cover of younger sediments and volcanics. It was found in a drill-hole (D433 of Tahal), 500 m south of W. Ish-she Railway crossing. It is assumed that it thickens towards the south.

The exact age of the brackwater series could not yet be determined. Picard (1932) ascribed to it the Lower Pliocene age (Pontian) "because it is covered without any conspicuous unconformity by Middle Pliocene". Micropalaeontological examinations made by Mr. Z. Reiss of the Geological Institute revealed in some of the samples a shallow-marine Neogene fauna: *Conorbina* sp., *Elphdium* gr. *crispum*, *Streblus beccarii*, *Miliolidae*, *Cibicides* sp., Cretaceous forams redeposited.

2. *The gypsum* (*g*)

In certain places within the area the brackwater series is overlain by gypsum beds from 2 in to 10 m total thickness.

The northernmost outcrop of gypsum is at 20194/23296; it was not found west of grid line E1999. From the thickness and character of gypsum outcrops within the area we may conclude that it thickens towards the south and disappears in the north and west.

Going south another change is observed; in the north the gypsum usually occurs in two distinct beds separated by a clayey-marly intercalation ("the transition marl") 0–2 m thick, whereas in the south (W. Ish-she, drill-hole D433) the gypsum occurs in many thin beds alternating with marl and chalk of the upper part of the brackwater series. These alternating gypsum marl beds reach in places a thickness of more than 50 m.

The gypsum, wherever it occurs, marks the end of the conditions which prevailed during the deposition of the brackwater series.

Since the gypsum never exceeds a thickness of a few metres, diapiric phenomena did not develop and it was always found in its proper stratigraphical position, except for one exposure (near the Muweilih bridge) where its occurrence could not be explained. On the other hand, because of its incompetency, the gypsum together with the intercalated "transition marl" are often thrown into intense intraformational folds (small-scale alpine structures, Figure 1).

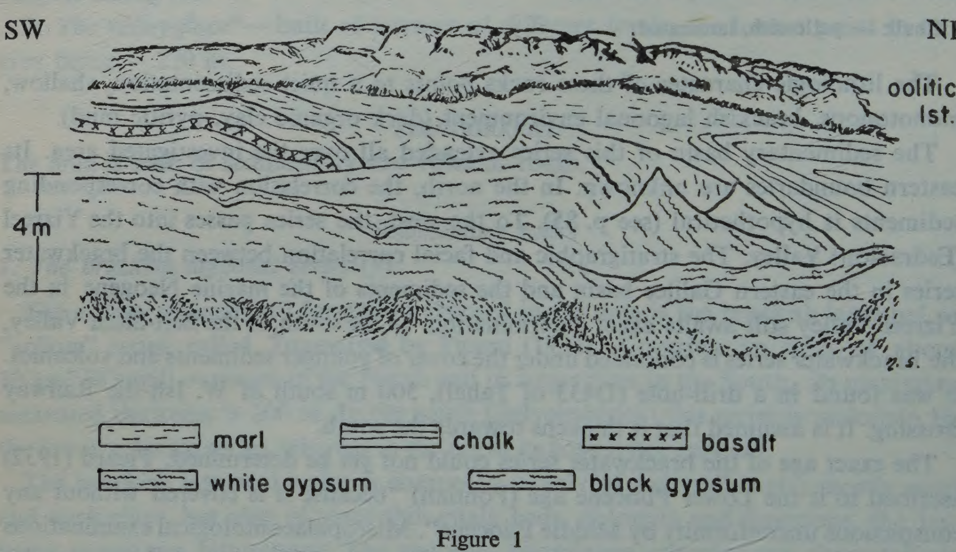


Figure 1
Intraformational folding in gypsum.
Quarry south of Menahamiya, 20255/22870.

3. *The lacustrine freshwater series* (*f*)

The brackwater series and gypsum are overlain by lacustrine beds, "the freshwater series", subdivided into three smaller units f_1, f_2, f_3.

f_1 — "Plattenkalk" — Picard 1932). The base of the freshwater series is built of platy white chalk, mostly soft but sometimes silicified and hard, its thickness varying from 5 m to 35 m. The chalk is sterile.

In addition to its thin platy bedding, this chalk is characterized by the lack of any clastic material, by lithologic uniformity and its occurrence all over the area, mostly

without great variations in thickness. Its freshwater lacustrine origin is assumed on the following grounds:

a) The gypsum indicates the end of lagoonal shallow marine conditions, i.e. sealing up. A renewed ingression of the sea would have brought a sedimentation similar to the preceding brackwater series, or, under more drastic conditions, even coarser clastics – sand and conglomerate, but not chalk.

b) The contact between the brackwater series (with or without gypsum) and the platy chalk is sharp.

c) On the other hand, the transition from chalk (f_1) to the overlying oolitic limestone (f_2) is, more often than not, gradual and sometimes indiscernible. The deposition of the latter in freshwater lakes is indicated by the *Hydrobia* fauna.

d) No marine fauna whatsoever could be detected in the platy chalk.

The sections of three outcrops, where the platy chalk is best exposed, are given below:

Loc. N. bank of W. Fajjas, 2 km E. of the Jordan. Thickness in m.

10. –	Tuff; calcitic and clayey binding material, isolated crystals 0.5–2 mm long of prismatic idiomorphic dark green pyroxene; baked xenoliths of limestone and chalk, mostly from the local Neogene rocks.
8. –	Scree. Steep slope.
1. –	Hard siliceous chalk; HCl residue: Needle-like silica.
–.60	Soft oolitic chalk, with some olivine grains.
1. –	Yellowish-grey porous tuff with grass-green olivine crystals, some of them fresh; calcitic binding material.
6.–	No exposure.
–.60	Soft white marly chalk; closely jointed.
–.60	Slightly marly soft white chalk.
–.20	Porous soft white chalk.
–.10	Soft limonitic marly chalk (dug).
2.–	No exposure.
–.30	Soft white chalk.
–.50	No exposure.
1.60	Soft white chalk; thin and pronounced bedding.
–.20	Porous light-grey chalk with 5–10% pyroclastic material (tiny pyroxene crystals and fine volcanic ashes) and secondary calcite crystals.
4.60	Palagonitic greenish tuff; calcitic binding material.
2.50	Palagonitic green tuff with calcite crystals.
12.–	Much weathered vesicular basalt and palagonitic tuff. Base not exposed.
51.80	

Section from 20205/23280 *WNW to* 20188/23283 (*Reuven*).

	Oolitic limestone.	f_2
7. –	Laminated soft chalk.	f_1
23.–	Scree. In the uppermost 15 m. sporadic chalk outcrops.	f_1
1.50	Layered gypsum.	g
3. –	Laminated gypsum with dispersed limonite and clay between the laminae.	g
1. –	Dense yellowish-brown limonitic marly chalk.	y
–.40	Strongly limonitic, slightly marly, soft, porous, greyish-yellow chalk; laminated. Base not exposed.	y

Section from 20000/23130 *towards* Δ + 205.2. *Dip*: 5./*WNW*.

Cover-basalt.

m.

15. – Scree.
6. – Basalt (upper scarplet).
15. – Tuff; badly exposed.
4. – Well-bedded hard chalk and porous oolitic limestone (lower scarplet).
4. – Scree. Probably chalk.
11. – Thinly-layered soft brittle white chalk, with a 40 cm thick hard siliceous oolitic band on top.
12. – Flaggy white chalk, with a 20 cm thick hard siliceous oolitic band on top.
5.– + Massive soft white chalk with hard concretions (fig tree scarplet), base not exposed.

f_2 — The platy chalk is overtain by *oolitic chalk or limestone*, which contains occasionally freshwater fauna: *Hydrobia frassi.* The oolites of varying size are built of a number of external concentric calcitic shells enclosing a void space. The rock contains in many cases clastic material: calcareous, pyroclastic or basaltic. Secondary opalisation and silification phenomena are common.

Lateral lithologic changes in the oolite and especially the appearance of coarse clastics and freshwater fauna enable the distinction of the oolitic chalk and limestone from the underlying platy chalk, and point to environmental changes.

The thickness of this unit is 0–20 m. In the west its top is unconformably covered by the cover-basalt (π). From Belvoir and southwards to W. Ish-she, it is mostly missing altogether. Here the cover basalt rests directly on the brackwater series. East of grid line E202 the oolite is overlain mostly by the variegated beds "f_3".

f_3 — The main characteristics of *the variegated beds* are:

a) Although the beds are still mainly calcareous, a large amount of clayey and pyroclastic material is admixed. Quartz grains however are very scarce.

b) A great variety of composition and colour.

c) Abundant lacustrine fauna and diversity of genera; among others also *Melanopsis* sp. (probably *laevigata*) but its occurrence here is still subordinated to other genera.

The most important outcrops of these beds are to be found in the following localities: on W. Fajjas, some 700 m south of Alumoth; SW of Fajjas river mouth, close to V–151; east of Tel-esh-Shahra, between W. Muwehili and W. Tuleh; on the El-Muntar ridge.

The description of some of the most characteristic "variegated beds" is given below:

Loc. 20225/22865, *el.* –150 *m* ("*strike-valley*").

The exposures are sporadic, the beds partly covered by soil; no continuous section could be made.

Sample 1*a*: dense lacustrine organogenic limestone, yellowish-brown, with a small amount of clayey and fine pyroclastic material; fauna: *Planorbis* sp. *major*, *Melania tuberculata.*

Sample 2*b*: limestone as above, oolitic, composed wholly of a species of lamellibranchia (6 × 10 mm), which, because of bad preservation, could not be determined.

Sample 1*c*: granular, detritic, light-brown limestone, with some clayey and pyroclastic material; greyish-pink soft chalk with clay and ashes.

Sample 2: granular, oolitic, yellowish-brown limestone, with pyroclastic material and freshwater gastropoda, mainly *Melania* (*tuberculata*?), alternating with greyish-pink, dense, fine-grained limestone with same gastropoda.

Loc. 20232/22881, *on Menahaniya-Gesher road* ("*Muweilih-bridge*").

Dip: 70°/ESE. Alternating beds of the following three types of rock:
Sample 1: soft grey chalk, admixed with clay and ashes, with abundant fauna: *Planorbis* (*major*?), *Neritina Karassuna*, *Melanopsis* (*laevigata*?) and others.
Sample 2: soft yellowish-brown limestone with ashes, built wholly of *Melania* (*tuberculata*).
Sample 3: dense, medium-hard, white to light pink limestone with *Melania* r sp.

Loc. 20220/22570, *el.* – 125 *m Bab-el-Muntar*.
Exposed section of 10 m. of alternating thin-bedded rocks dipping 70°/SSE.
Sample 5: organogenic limestone with *Neritina* sp., *Melania* sp., *Unio* sp.
Sample 4: clayey siltstone, limonitic, ochre-coloured, laminated.
Sample 3: greyish-brown silty marl with *Melania* sp.
Sample 2. light-brown clayey siltstone with plant remains.
Sample 1c: brittle, brown, detritic limestone with badly preserved *Unio* and *Dreissensia*.
Sample 1b: brittle, brown, calcareous sandstone (dark minerals and some quartz).
Sample 1a: grey sandy-calcareous siltstone (large amount of dark components).
Sample 1: grey, fat, silty clay; closely cracked.

From observations in the field it was established that the deposition of the variegated beds (f_3) followed the oolite (f_2) without any conspicuous break. In the east, the variegated beds reach a thickness of several tens of metres, whereas towards the west their thickness is reduced to a few metres (W. Fajjas outlet) and finally they wedge out.

Lateral lithologic changes as well as intense structural disturbances prevent us from subdividing this unit.

The variegated beds often alternate with pyroclastic beds and lava sheets and are overlain mostly by the cover basalt (π).

The lithologic faunistic diversity of these beds and their limited occurrence, confined to a comparatively narrow belt, as well as their stratigraphical position in the uninterrupted sequence, help us visualize the morphotectonic conditions which prevailed during their deposition. These will be referred to in the palaeogeographical summary.

4. *The "Melanopsis stage"* (*m*)*

The "*Melanopsis* stage" built of fluviatile lacustrine sediments varying in lithology from conglomerates to chalk and limestone, and rich in freshwater fauna, was previously described by Blanckenhorn (1897) and Picard (1932). A detailed description of the fauna was given by Picard (1934) and its stratigraphical and structural position was determined by the same author (1932), who ascribed to it the Upper Pliocene age (Levantinian), i.e. older than the cover basalt (π) and preceding the main faulting phase. 1952, Picard revised this opinion, proposing the Lower Pleistocene age for this formation, timing it posterior both to the cover basalt and the main faulting

* Former workers in this area used the term "stage" for this formation. As the degree of stratigraphical time unit to be attributed could not be defined, and in order to avoid confusion, this term is retained.

phase. The results of the present work led the author to the same conclusion regarding the sequence of events although the exact age of the "*Melanopsis* stage" still remains uncertain.

The two main locations where this formation occurs are described below. A third one (Um-Sabune) is added here, although its correlation is problematic.

Loc. 'Ubeidiya (see Figure 2 *and sect. I*).

At this locality the Melanopsis-stage beds are exposed over an area of about 1 km^2, being mostly covered by alluvium. In the west they reach the – 175 m elevation; they dip steeply to the SE and disappear below the cover of younger quaternary horizontal sediments. They are characterized by the predominance of clastic rocks, abundance of freshwater fauna — mainly *Melanopsidae.*

Detailed study of the 'Ubeidiya exposure revealed the lenticular character of many of thses beds, wedgings-out and lateral changes (Figure 2).

Two sections from the 'Ubeidiya exposure are given below, one in the SW, the other in the NE.

Section 1 (*SW*).

Sample 13: Granular, soft, white, sandy chalk. The sand is fine, mainly quartz.

Sample 12: Very soft, light, grey marly chalk, with well preserved fauna of: *Melanopsis obediensis, Melanopsis buccinoidea, Mealania rhodiensis, Bulimus* (*Bithynia pisidica, Theodoxus jordani*).

Sample 11: Soft oolitic chalk.

Sample 10: Cross-bedded, laminated, sandy, yellow siltstone; components: Mainly very fine to fine transparent subangular quartz, and some dark minerals.

Sample 9: *Melanopsis–Unio* bank.

Sample 8: Medium-hard, limonitic, yellow chalk.

Sample 7: *Melanopsis* conglomerate. Components: Angular weathered basalt fragments up to 2 cm large; patinated shiny flint-fragments 5 mm long; gastropoda: *Melanopsis nottlingi* (the most frequent), *Bulimus pisidica, Melania tuberculata, Theodoxus jordani.* Binding material: Calcareous.

Sample 6*a*, 6*b*: Light brown, limonitic, silty marl, with some very fine sand, rich in: *Melanopsis* (*obediensis*?), *Theodoxus jordani.*

Sample 6: Gastropoda conglomerate with patinated flint fragments.

Sample 5a: *Melanopsis* conglomerate; lithology same as sample 7; fauna: *Melanopsis obediensis* var. *coroniformis.*

Sample 5: Hard, dense, lacustrine, "cauliflower"limestone.

Section 2 (*NE*).

Sample 13: Granular, sandy chalk.

Sample 15: Ochre-yellow, clayey siltstone. Components: Mainly very fine subangular, shiny quartz grains; some very fine dark grains.

Sample 14: Same as sample 15, with well-sorted sand.

Sample 4: Very soft, light grey, marly chalk, with well preserved fauna of: *Melanopsis nottlingi, Melanopsis obediensis, Bulimus pisidica, Melania tuberculata, Theodoxus* sp.

Sample 3: Soft oolitic chalk.

Sample 2*a*: Ochre-yellow marl.

Sample 1: Breccia conglomerate. Components: Well-patinated, shiny, 5 cm long flint fragments. Binding material: Dense, white, calcareous.

West of the two above-mentioned sections, and separated from them by a 150 m wide alluvial belt, two beds of light grey calcareous siltstone are exposed on the

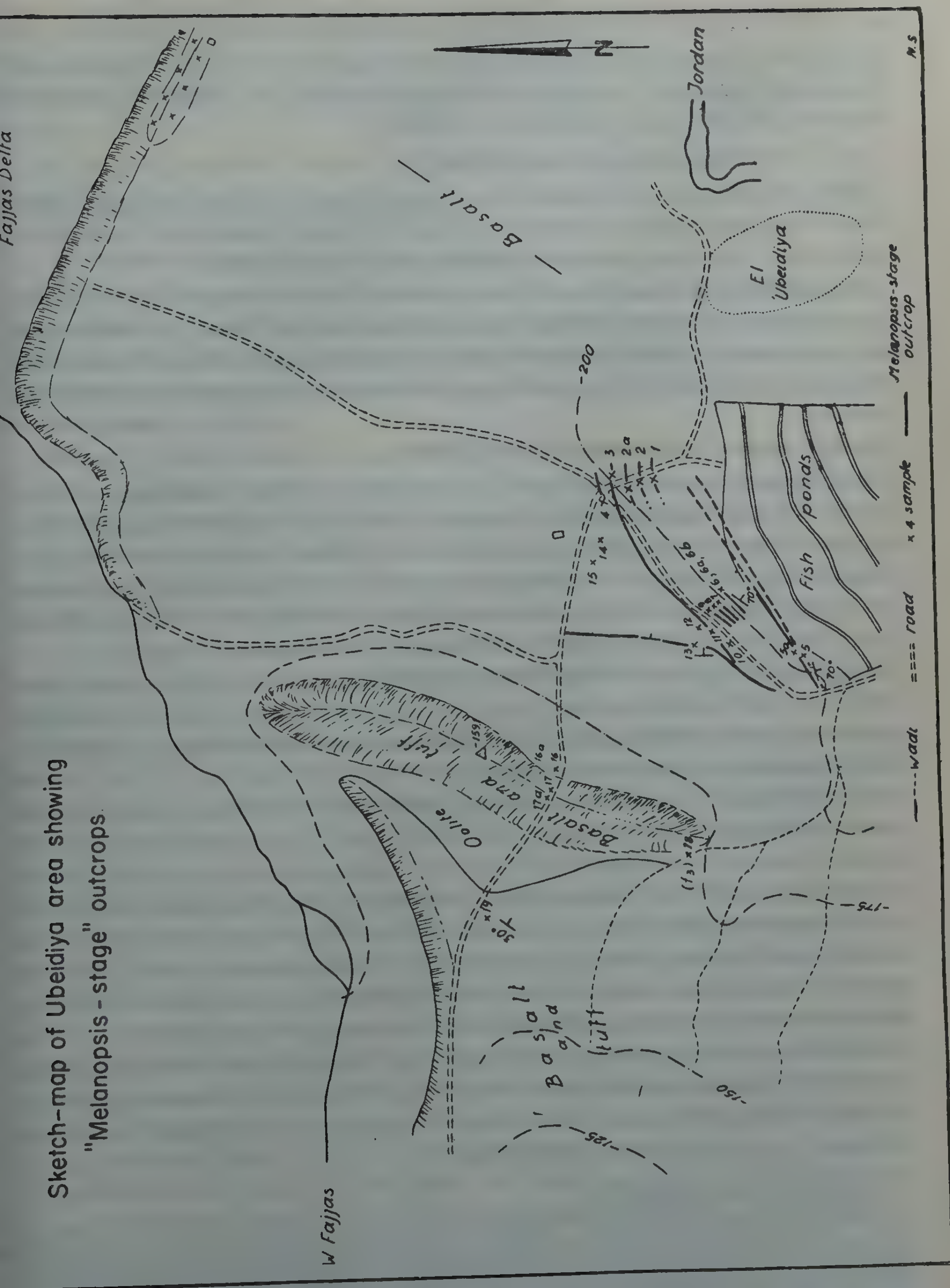


Figure 2
Sketch map of 'Ubeidiya area showing "*Melanopsis* stage" outcrops.

eastern flank of the V- 159.1 basalt-ridge. These beds (samples 16, 16a) are lithologically similar to sample 14 and belong to the *Melanopsis* beds. Provided that no structural disturbance is concealed below the alluvium, the computed minimum thickness of the *Melanopsis* beds would be 200 m.

Loc. Manahamiya-Gesher (*Iraq-el-Ahmar*).

Sporadical outcrops of *Melanopsis* beds appear south of Menahamiya and down to Jisr-el-Majami, between Tel-esh-Shahra and El-Muntar ridges in the west and the Jordan River in the east. It is best exposed at the W. Gharb outlet.

The similarity of these beds to those described from 'Ubeidiya, in its faunistic assemblage, lithology and structural position is self-evident. Both at 'Ubeidiya and here, the highest elevation reached by the *Melanopsis* beds is about – 175 m, their dip is very steep (60–70°) in the west and becomes more moderate to horizontal in the east.

Loc. Um-Sabune, at the base of Belvoir-block.

The sequence exposed here has at its base (el. – 150 m) conglomerates with elements of flint, basalt and oolitic limestone, overlain by mostly fine-clastic rocks: Alternating fine varved sandstone, siltstone, clay, shales and chalk. The alternating beds are thin and point to a rhythmic sedimentation. The total exposed thickness is 150 m. The highest elevation at which these beds were found is – 100 m (compared to el. – 175 m in 'Ubeidiya and Iraq-el-Ahmar). No fossils were found.

Blanckenhorn (1907) and Picard (1932) refer this outcrop to the *Melanopsis* stage. The lithological similarity and the typical steep dip (30–70°) to the SE, support this correlation. On the other hand, the complete absence of fossils and the comparatively higher morphological position are against it.

The "*Melanopsis* stage" beds, covered discordantly by Lisan-marl and alluvium, form a high-level terrace incised by the bends of the Jordan and dissected by its western tributaries. The character of their rocks suggests that during their deposition a pronounced relief was formed, which supplied the clastic material. Among the most frequent components are flint pebbles (Eocene?), quartz-sand (Neogene of the northern part), elements of the brackwater series and gypsum, as well as basalt pebbles. This, and the structural position of the *Melanopsis* beds serve to indicate that their deposition took place during and after the main faulting phase.

The steep dips at the western fringe of this internal basin still remain to be explained. They could have been caused either by a later and weaker tectonical subsidence, confined to the central part of the valley, or by the compaction under load of the sediments in the centre of the depression.

5. *Lisan marl and alluvium* (*g*)

The post-"*Melanopsis* stage" lacustrine–fluviatile sediments (Lisan marl and alluvium) are tectonically undisturbed. For the reasons mentioned above, they were not included in the present work. The Lisan marl was dated by Picard (1900) as Middle Pleistocene.

The volcanic formations and their relations to the sedimentary formations

The central Jordan Valley is remarkable for its basic volcanic rocks — lavas and pyroclastics. These occur all along the exposed stratigraphical sequence all over the area.

For mapping purposes, they were divided into three main groups:

1. *The Neogene volcanics* (*Mio-Pliocene*) (*v*)

a. The oldest exposed formation in the area is volcanic.

At the base of the Belvoir block, a thickness of 200 m of alternating basic lavas and pyroclastics are exposed by faulting. These are overlain by 150 m thick brackwater series. Due to the SW tilt of the Belvoir block, this lower volcanic formation disappears in the south, whereas at 2008/2229 (NE corner of Belvoir block) one can see the oldest rocks exposed in our area.

Dating of these volcanics is impossible before the exact age of the overlying sedimentary brackwater series is determined. Their relation to the lower volcanics (Miocene) in the north (Kinnereth–Tiberias) will be dealt with later.

No intercalated sediments have been found as yet though the sequence is not built exclusively of basalt lava sheets. The amount of pyroclastic beds, from coarse agglomerates to tuff, is considerable, especially in its lower part.

b. Basic lavas and pyroclastics, of the volcanic explosive type, appear throughout the whole sedimentary sequence, from the brackwater series and up to the variegated beds.

Most of the exposed sections are built of interchanging sedimentary and volcanic rocks – "mixed". Sections in which these volcanics are not encountered are rare, and in some places the sediments are completely missing and the whole column consists of lava sheets and pyroclastic beds (W. Et-Tina along grid-line N2301, and along grid-line N2320).

Many of the pyroclastic beds are in fact redeposited and therefore sedimentary. Of special interest are two thin banks of *Dreissensia* intercalated within volcanic rocks; the one at Ein-Anin (see also Picard 1932), the other at Ein-Jurm (Figure 4).

In the "mixed" sections the relations between sediments and volcanics can be studied. Lava flows and tuff intercalations of various dimensions occur at every possible stratigraphical horizon. Nowhere could intrusive bodies be recognized, except for some small-sized apophysae and impregnations. Some of the typical localities showing the volcanic-sedimentary intercalations are illustrated in the attached figures (Figures 3,4,5,6,7) and geological cross-sections.

In certain places (Kh. ed.-Deir, W. Idma — E. of bridge) the base and top contacts of lava sheets can be observed. Only slight contact-metamorphism in the sedimentary rocks was observed at the contact with the overlying lava-sheet and none on top of it.

The source of the lava and pyroclastics has not yet been detected. The character of the latter suggests a nearby source or sources. At two localities, one near the

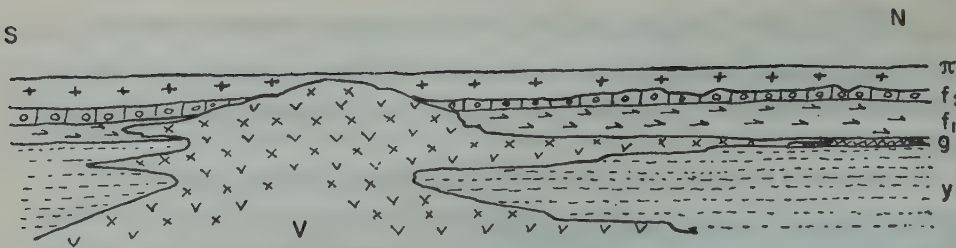


Figure 3

S–N diagrammatical cross-section west of Menahamiya.

f_2 —	oolite	y —	brackwater series
f_1 —	laminated chalk	π —	cover basalt
g —	gypsum	ν —	Pliocene volcaniès (lava and pyroclastics)

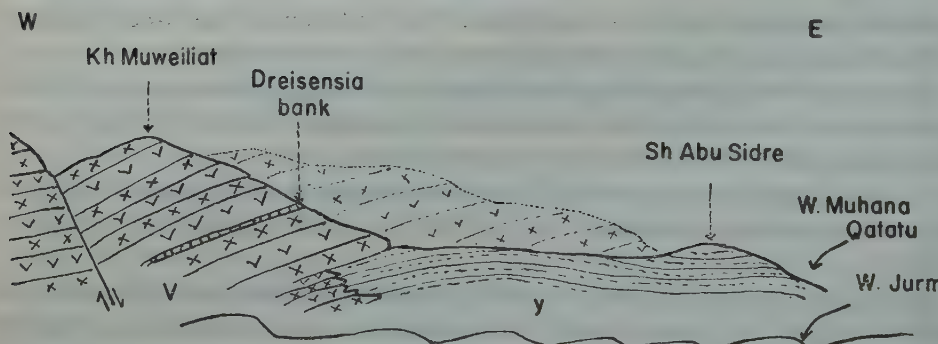


Figure 4

Relations between Neogene volcanics and brackwater series, west of Menahamiya.

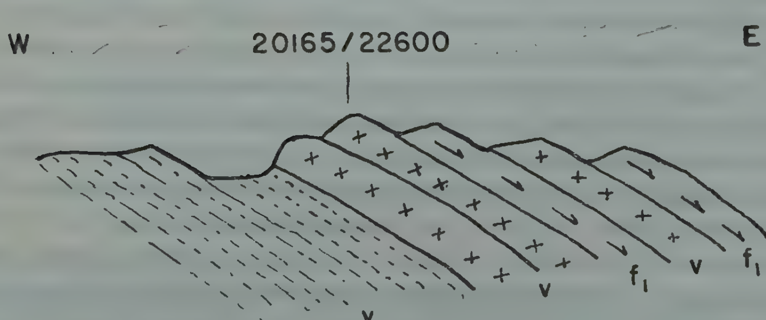


Figure 5

Relations between Neogene volcanics and sediments in Wadi Idma.

Fajjas outlet, the other on W. Ish-she, volcanic plugs are suspected. The material consists of chaotically piled-on tuffs and coarse agglomerate.

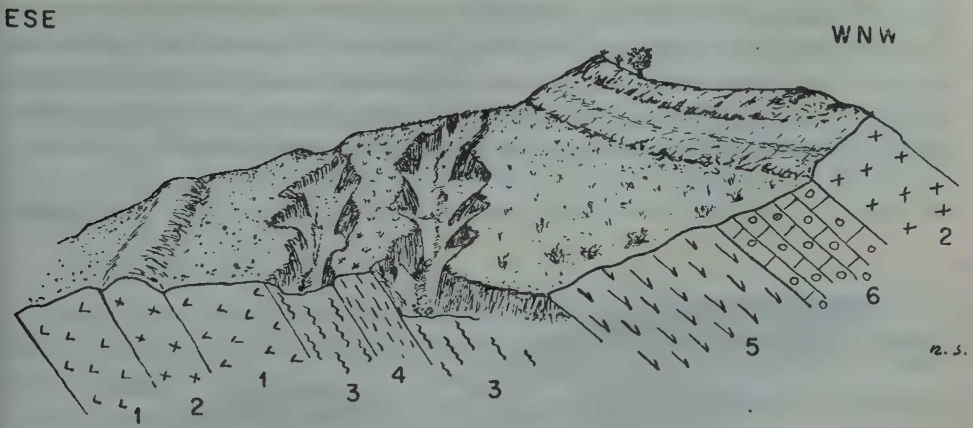


Figure 6
Tel-esh-Shahra gypsum quarries.

1 — tuff	4 — transition marl
2 — lava	5 — laminated chalk
3 — gypsum	6 — oolitic limestone

Figure 7
Exposed section on northern bank of lower Fajjas.

The pyroclastic rocks are best developed between W. Fajjas and W. Bira. They occur also north of W. Fajjas (Bentor 1946), but they grow less important and finally disappear as one goes north. The same phenomenon is observed south and west of our area. It is assumed, therefore, that these pyroclastic rocks represent a period of explosive volcanic activity having its centres in and near the investigated area. This volcanic activity went on during the deposition of brack- and freshwater series alike, up to the regional outflow of the cover-basalt.

During this period (Neogene) the central Jordan Valley was the site of shallow lagoons and lakes, disturbed by constant volcanic outbursts. The irregular and sporadic occurrences of the dark-coloured and mostly resistant lava sheets and pyroclastic beds, interposed between the light-coloured and mostly soft sediments, lend to the present day landscape a diversity of form and colour. Later faulting which broke the country into down-stepping tilted blocks sometimes made it difficult to tell whether a certain basalt-ridge was a dyke or a tilted flow-basalt sheet*.

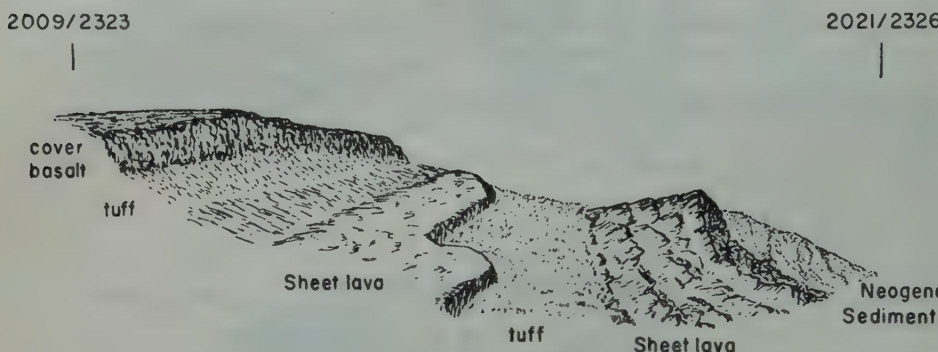


Figure 8
Lava tuff country, north of Menahamiya.

2. *The cover-basalt* (π) (*Plateau-basalt of former authors*)

The Sirin and Belvoir plateaux, as well as the faulted tilted blocks in the east, are covered by flows of the cover basalt. The thickness of this basalt in the east varies from 30 m to 50 m; in the west it is much thicker. It lies with an erosional unconformity directly on sedimentary or volcanic Neogene rocks. The basalt is composed exclusively of flows, and in many instances the base and top of individual flows are clearly perceptible. Here and there, a small-scale trapp-landscape developed.

The most common rock is a feldsparphyric ophytic basalt, in many cases with olivine-phenocrysts. The latter are usually alterated (mostly pseudomorphic limonite). The olivine-basalts and basanites of the underlying Neogene volcanics contain mostly fresh, unaltered olivine-phenocrysts. On the whole, the cover basalt is distinguished from the Neogene volcanics in that it is of a coarser grain, microphyric and porous.

The typical macrostructural features of the cover-basalt are: Columnar, spheroidal or large blocky jointing; its weathering colour is grey to bluish-grey.

The outflow of this basalt preceded the main faulting phase and this accounts for the various structural positions it assumes, capping the faulted and tilted blocks.

How far east does the cover basalt extend, is not known, because of the downfaul-

* Some of these basalt-ridges were interpreted by Picard (1932) as dykes. Later, Picard (1900) expressed his doubts about some of them.

ting and younger Pleistocene cover. It can be stated, however, that within the investigated area the cover-basalt is almost always found on top of the Neogene formations.

The source of the cover basalt ("π") is not known. It seems most likely that it was outside the narrow belt of the central Jordan Valley, and in our opinion it is to be sought in the west and south-west.

Wherever the topography allows it, the cover-basalt is covered by a rich residual dark-brown soil. The hardness of the rock and its coarse jointing pattern account for the steep erosional or fault scarps it forms. These scarps, cutting abruptly the capping basalt masses help to define the main structural outlines of the area.

3. "*Young basalt*" (β)

Under this name are included basalts youger than the cover basalt. These are known from adjacent parts in the Jordan Valley and eastern Galilee, but here their presence is not certain.

Two types of these younger (Middle Pleistocene) basalts were described by different authors:

a. The basalt of the volcanic necks of the Horns of Hittin and Tel-Maun, W. of Tiberias (Bentor 1946).

Identical occurrences have not been found between W. Fajjas and W. Ish-she. The topographically high points of the Sirin and Belvoir plateaux (Δ 312.1; Δ 353.5; 367.8) are not, in our opinion, the eruption centres of extinct volcanos, but only structural morphological peaks of the tilted fault blocks.

b. The Yarmuk–Naharaim basalt (Picard 1932).

At the two above-mentioned localities, close to the investigated area (at present outside the territory of Israel), Lower-Pleistocene beds ("*Melanopsis* stage" and Naharaim gravel) are covered by basalt flows. The latter, in their turn, are covered by the lacustrine Lisan-marl.

Within our area, the basalt exposed at the southern corner of the Fajjas delta, probably belongs to the same group. Two other basalt out-crops of uncertain age, more to the south, may also be included here. Anyway, the Yarmuk–Naharaim basalt is confined to the floor of the Jordan Valley and was not found at higher levels.

STRUCTURE

"Thou hast made the earth to tremble;
thou hast broken it:
heal the breaches thereof;
for it shaketh".

Psalms, 60:2.

The predominant tectonical element in the 20 km long western rim of the Jordan Valley investigated is taphrogenic.

The older, presumably existing, folding elements, are not subjected to direct observation; they are concealed under a thick cover of Neogene and Quaternary sediments and volcanics.

The western rim of the valley, from kibbutz Kinenreth to W. Ish-she, is built of step faulted tilted blocks. The structural down-throw towards the depression is not expressed in a single large and long master fault, as seems to be the case at the eastern rim of the depression, but in a system of small normal faults. This is, at least, what could be gathered from surface data.

A similar picture is known from the western Dead Sea area: Blake, Picard, Shaw, Vroman.

Figure 9
Down-stepping faulted blocks. Western rim of the Central Jordan Valley

The degree to which these faults represent the structure at deeper levels of the crust is in the meantime a subject of a speculative nature (see p. 88).

With the exception of the Belvoir fault, the observed faults within the area have the following common traits:

1. Never could a fault line be traced for more than 4 km distance (mostly even less).

2. The vertical displacement of each individual fault does not exceed 150 m, and usually does not die out gradually, but abruptly.

The dip of the faults could not in most of the cases be exactly measured, but wherever it could be estimated it was found to vary between 60–80°.

4. The direction of the fault lines forms an acute angle with the general N–S direction of the Jordan depression .North of Tel-esh-Shahra this deviation is to the NNW, whereas south of it the deviation is to the SSE (see fault pattern map).

5. The faults are arranged in parallel N–S en-échelon belts. These en-échelon belts descend in steps from west to east and disappear below the post-taphrogenic formations. We can therefore speak about longitudinal rows of en-échelon faults.

6. A striking feature of most of these faults is the tilt of the downthrown block towards the upthrown one, suggesting antithetic rotation to the west ("antithetische Verwerfungstreppen" of H. Cloos). The step blocks of the western row are less rotated than those of the more eastern rows. Tel-esh-Shahra block in the east is tilted 70° to the WNW. This strong tilting of Tel-esh-Shahra and its position at the crossing-point of the two above-mentioned directions (NNW and SSE) of the faults account for its conspicuous morphological aspect (Figure 11).

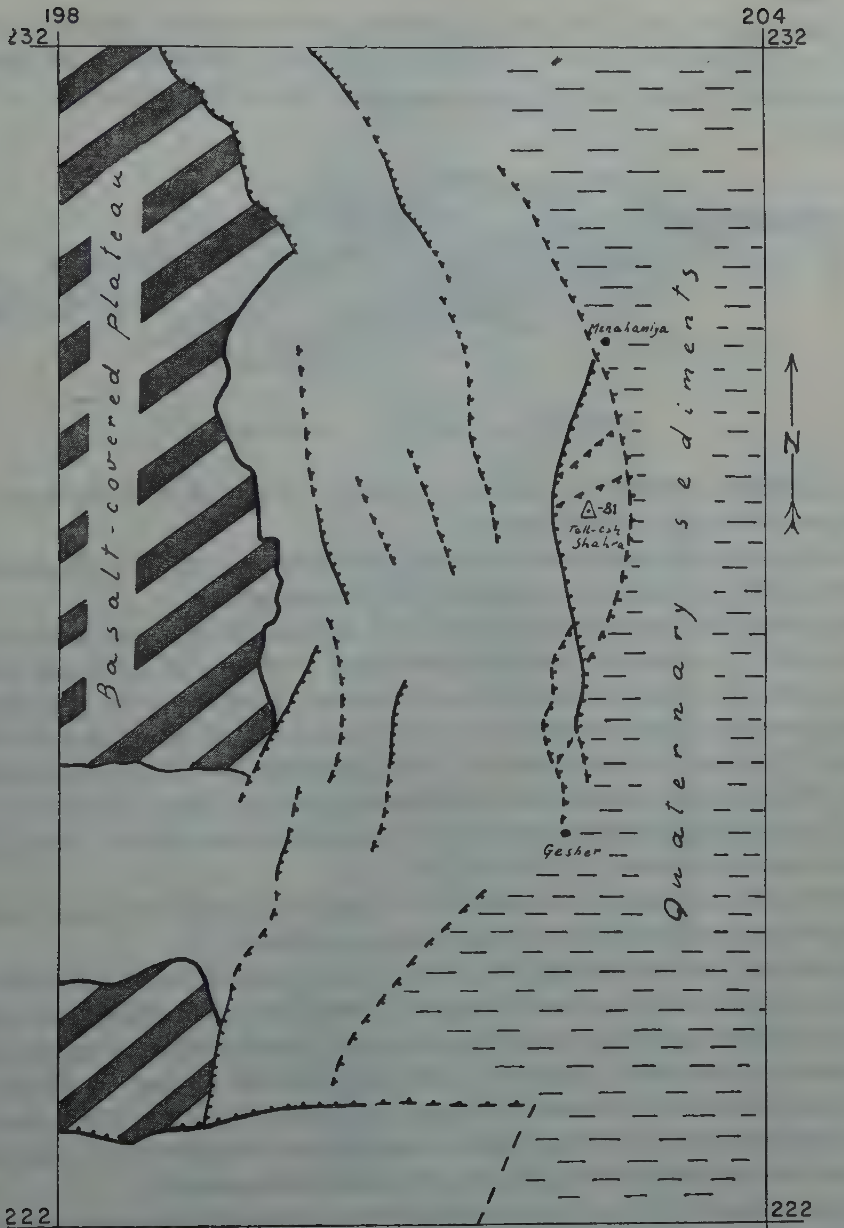


Figure 10
Fault pattern of Fajjas–Bira area.

7. No directly connected igneous or volcanic activity was observed along the fault lines.

8. The general surface outline of the individual blocks is usually long and narrow. They are mostly up to 1 km wide (between two faults). Wherever a wider space is mapped clear of faults, there is reason enough to believe that they have not been detected.

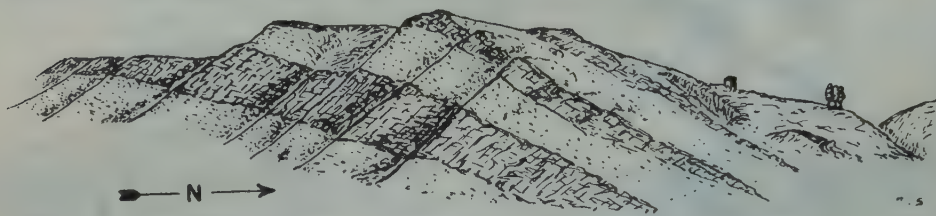


Figure 11
Tel-esh-Shahra (Δ–81.2) — tilted block.

9. Landslides of different dimensions are often associated with the faults and sometimes look like real fault blocks.

The above generalizations do not hold good with two conspicuous structural features in our area: the Belvoir fault and the El-Muntar block.

The Belvoir fault strikes E–W. Its trace runs south of W. Bira and parallel to its lower course. Its maximum vertical displacement is in the east and grows weaker towards the west, where it can be followed up to loc. 1945/2238. In the east, where it disappears under young Quaternary cover, it is most probably cut off by a N–S fault or faults. The intersection of the Belvoir E–W fault with the N–S fault system exposed, at the NE corner of the block, the stratigraphically lowest visible horizons in our area. The maximum stratigraphical throw observed is here 450 m! Close to the Belvoir citadel it is about 150 m (Figure 12).

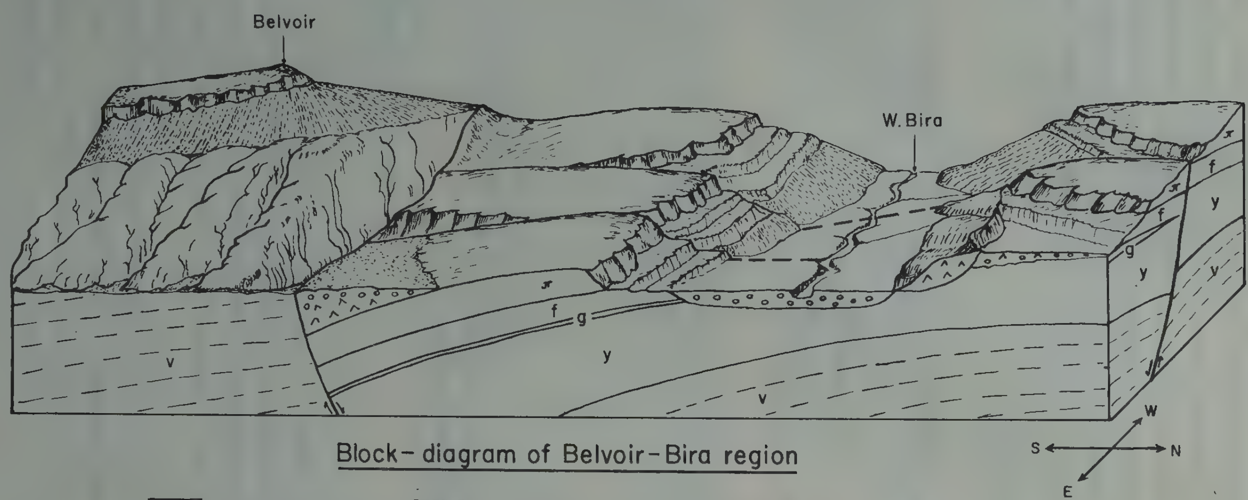
In the east it brings the cover-basalt ("π") against the Neogene volcanics, whereas in the west, cover basalt is found on both sides of the fault*.

The Belvoir fault belongs to the regional system of crescentic faults, which brought about the tilted block structure of eastern Galilee. The main displacement along this fault is to be dated as post cover basalt, but it is suspected that it started earlier, although on a small scale. This earlier initiation of the Belvoir fault is offered here as an explanation of the complete absence of freshwater series south of the fault (on the upthrown side), although other possibilities are not excluded. (As shown on the map, two more E–W faults of pre-cover basalt are suspected.)

Coming from the NE, one cannot miss the morphologically prominent fault scarp at the NE face of the Belvoir block. The scarp is steep and grooved with sharp and parallel furrows (Figure 15).

* The Belvoir fault had not been indicated by former workers, but its western continuation N of Kafra village was marked in Picard's original 1:100,000 map of August 31, 1953.

Figure 12 ⟶



Block-diagram of Belvoir-Bira region

π – cover basalt
v – Lower Neogene volcanics
f – freshwater series
g – gypsum
y – brackwater series
alluvium
Landslides
fault

The El-Muntar block, N of Kibbutz Gesher, is a long and narrow N–S ridge 1 km long and 100–200 m wide. It is built of rocks known elsewhere in the area (Figure 13), and is bounded by two N–S faults. It deserves special attention because of its unusual tilt of 70° to the south and SSE. It is not easy to explain the mechanism which brought about this exceptional structure. We must not, however, overlook the fact that east of a certain line (appr. grid-line E202) the structures tend to be chaotically arranged. The degree of disturbance is stronger than in the west: faults and fractures are more closely spaced, tilting is more steep, and flexures are common (El-Mura). It looks as if the blocks were tumbling down. We are here nearer the centre of the trough.

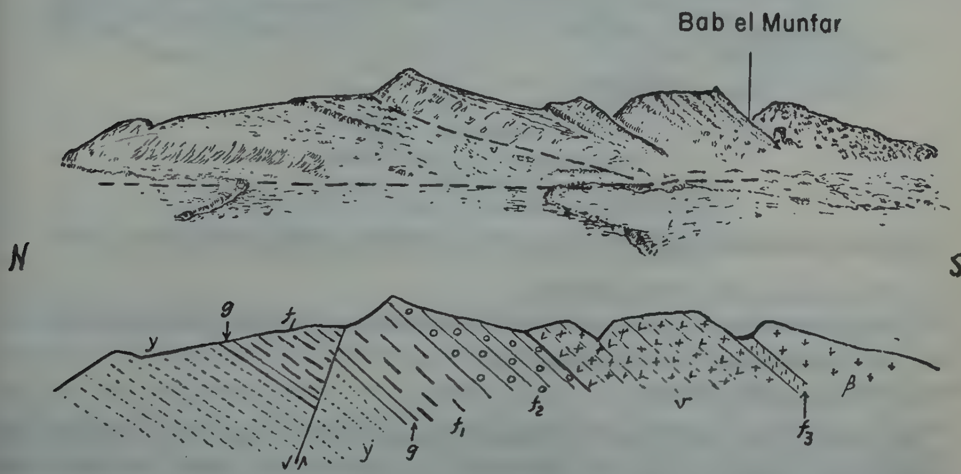


Figure 13
Sketch and section of El-Muntar.

f_3 — variegated series		β — basalt of uncertain age	
f_2 — oolite		ν — basalt and tuff (Plioc.)	
f_1 — laminated chalk			
g — gypsum			
y — brackwater series			

Endemic folding. Several of the faulted step blocks are locally and moderately folded or flexured. This folding is not strong and only secondary to the faulting. The most pronounced flexuring in this area affects the El-Mura block (sections V,VI). Rotational tilting to the west coupled with strong flexuring to the east make of the El-Mura block an anticlinal bend.

Hot springs have not been encountered in this part of the Jordan Valley, but they probably existed in the past. At loc. 20105/22025, travertine, similar to the one which is being deposited now in the Tiberias hot springs, is filling up a large fracture splaying out of Beit Yosef fault.

GEOMORPHOLOGY

The land forms of the central Jordan Valley truthfully express its structural evolution.

The intense geologically young faulting left its marks on the present-day landscape. The Jordan Valley is a long and narrow depression. From W. Fajjas to W. Ish-she both its eastern and western rims rise 550 m above the valley floor.

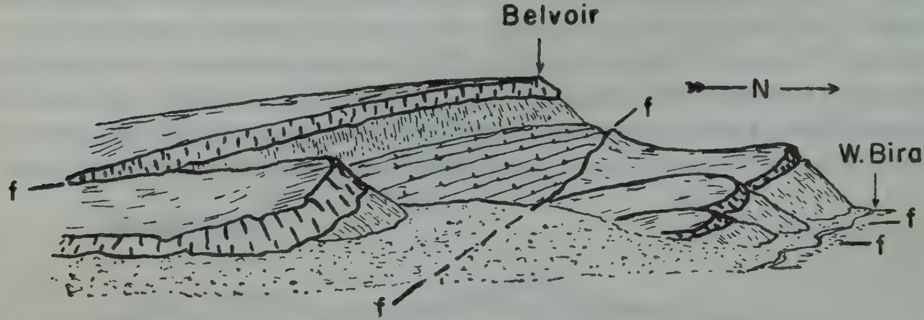


Figure 14.
Faulted blocks south of Wadi Bira.
Beith–Yosef fault and block foreground left.

The most important factors responsible for the present-day morphology are:

1. The young and intense faulting.
2. The contrast between the sedimentary and volcanic formations in the area.
3. A comparatively small drainage area.
4. The semi-arid climate.

The faulting was the last and strongest tectonical event in the area. Sinking movements of the valley floor occurred also after the main faulting phase, but these were much less important. These later and weaker movements of the valley floor, together with climatic changes, account for the oscillations of the level of the internal lakes during the Pleistocene.

The sedimentary formations and the pyroclastics are mostly soft and not resistant, whereas the extensive hard lava-sheets provide a protective cover. Most of the sedimentary and pyroclastic rocks are permeable, the climate is semi-arid, and torrential rains or cloud-bursts are not common. As a result, the erosional power of water is not great, and the greatest amont of denudation is performed by landsliding and probably to some degree also by earthquakes.

The steep slopes which bound the plateaux in the east are fault scarps, whereas the hills at their foot are step faulted blocks.

The escarpment is breached in three places: in the north by W. Fajjas, in the centre by W. Bira and in the south by W. Ish-she. All of them come from the north, then bend and turn east. Their lower course is parallel to the general strike of the east Galilean tilted blocks. The lower course of W. Bira, for instance, was directed by E–W faults, the Belvoir fault being one of them. Hypotheses on the evolution of W. Fajjas were proposed by Picard (1932) and Bentor (1946).

With the exception of these gaps, the edge of the escarpment forms the watershed

between two systems of rivulets and gullies. To the west of the escarpment edge the rivulets run sluggishly down the cover of the tilted blocks in a southwestern direction; to the east, short, parallel and steep gullies run down the slope towards the valley floor .The pattern and gradient of the latter is controlled by the nature of rocks they

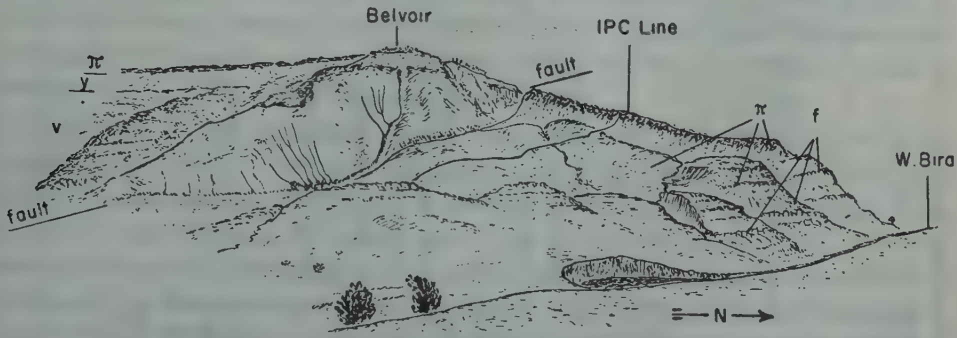


Figure 15
The Belvoir fault seen from 20160/22400.
v — lower volcanics y — brackwater series
f — freshwater series π — cover basalt

cut through and by the structural lines. The volcanics and the oolitic limestone are porous or jointed and therefore permeable. The gullies cutting through these rocks are parallel and widely spaced, with convex shaped spurs between them. In the larger exposures of the soft and less permeable brackwater series and platy chalk, leaf-shaped amphitheater-headed valleys with a dense dendritic pattern are formed. Wherever a gully runs down a fault scarp, it is steep and V-shaped; whereas on top of the fault steps it starts winding and its gradient is low. The erosive power of these gullies is small. The accumulated scree of the steep slopes is not dealt with rapidly enough by these small gullies, and little material is carried by them to the Jordan. The action of creep and landslides is more efficient.

The transport ability of the three larger wadis (Fajjas, Bira and Ish-she) is not much greater today. It is therefore assumed that at least in this part of the Jordan Valley there is no filling-up of the valley with material transported from sources outside the valley. The valley feeds on itself.

PALAEOGEOGRAPHICAL SUMMARY

Age	Tectonic activity	Volcanic activity	Physiographic conditions	Sedimentation
q	None	Unknown Volcanic activity, mainly lava flows in the centre and outside the depression.	Similar to recent "Lisan"–lake	Rythmic sedimentation of evaporites in the centre; clastic material on the fringes. Lacustrine-fluviatile fauna in the base and margins.
m	Slight subsidence of the valley floor	Unknown	Pronounced relief; abundant water-supply	Great variety of lacustrine-fluviatile sediments, clastics predominant: flint and basalt conglomerates, quartz-sand, silt, clay and calcareous rocks. Rich fauna — mainly Melanopsidae.
Plio-Pleist. transition	Main faulting phase		Main phase of rift-valley creation	
f_3	Rising of the western border of the depression.	Growing volcanic activity, mainly of the explosive pyroclastic type within the area and N of it; ar the end: extensives basalt flows (π) on a re- regional scale, coming from outside the area.	Considerable relief. The lakes are restricted to the centre of the area; the fringes undergo erosion.	Lacustrine-fluviatile, mainly calcareous with considerable admixture of pyroclastic material. Thriving freshwater fauna; variability of genera.
f_2	Western border of the depr, ession rising slowly.		Considerable relief; freshwater lakes.	Freshwater lacustrine oolitic limestone and chalk, with some clastic material of volcanic origin. Appearance of freshwater fauna (Hydrobia).
f_1	None	Mainly explosive volcanism confined to the area.	Moderate relief; (arid climate ?) freshwater lakes.	Monotonous, lacustrine, thinly bedded chalk; little or no clastic material. No fauna.
g			Sealing up of lagoons	Gypsum in the centre
y	Slow subsidence bringing about ingression of the sea		Moderate relief; lagoon landscape	Lagoonal-shallow-marine, brackwater sedimentation of alternating mud, silt, marl, chalk and dolomite in the centre; more sandy in the NE. Neogene shallow marine microfauna.
Lower Neogene	Faulting	Extrusive lava-flows and pyroclastics; the source probably in the south and SW	Pronounced relief; strong erosion.	Continental fluviatile and lacustrine "red series"

STRATIGRAPHICAL CORRELATION OF THE NEOGENE SEDIMENTS WITHIN THE INTERNAL BASIN OF THE CENTRAL JORDAN VALLEY

When we attempt to correlate the sedimentary formations within the central Jordan Valley (Tiberias–Beit-Shan), we are faced with certain difficulties caused mainly by later tectonic events. As a result of the faulting the greatest part of the Neogene rocks is buried deep under a Quaternary cover. Those, which can be directly studied, are exposed in two narrow belts bordering the valley.

In the west, another structural feature complicates the study of this narrow belt: the regional tilt to the SSW of the East Galilean tilted blocks. The exposed eastern face of these blocks thus dives down towards the south. In the north (Herodes Mt.), the lowermost Neogene formation, the "red series" is exposed. This, however disappears north of W. Fajjas, and only the freshwater formation is exposed along 2–3 km. Then the upper part of the brackwater series appears here and there due to the intricate fault pattern between Menahamiya–Gesher. The Belvoir fault causes the lower Neogene rocks again to be exposed, but the southern tilt persists. South of W. Ish-she only the cover-basalt still rises above the young quaternary sediments and finally disappears north of Beit-Shan (section IX).

On the eastern shore of Lake Kinnereth, Neogene rocks are exposed round Ein-Gev. These are mostly sandy rocks.

A correlation between the various Neogene outcrops, from Tiberias and Ein-Gev down to Beit-Shan, is attempted here.

The continental "red series" (*r*) (Picard 1932, Bentor 1946)

These fluviatile-lacustrine beds are exposed along the western escarpment from Herodes Mt. to 5 km south of it. They are intercalated with thick basalt sheets, which are thicker in the south and wedge out in the north. The age attributed by former workers: Miocene.

Two possibilities of the extension over the area of these continental beds (or their equivalent) are considered here:

1. The "red series" were not deposited farther south. They belong to a small basin restricted to the northern corner (Tiberias–Moshav Kinnereth). Farther south, the intercalated basalts take up the whole sequence.

In this case, part of the lower volcanics of Belvoir block and Sharona escarpment are equivalent in time with the "red series", which are missing here, and the basalts here rest unconformably directly on the Cretaceous – Lower Tertiary complex. (The correlation of the coarse pyroclastics and agglomerates at the base of Belvoir volcanics with the red series in the north is highly conjectural.)

2. Another possibility must not be excluded: The presence of equivalent continental beds (or part of them) below the lower volcanics of Belvoir. This would imply a considerable augmentation of the Neogene volcanics in a southern direction.

The brackwater series (*y*) is comparatively thin: 75 m (Bentor 1946) in the NW,

whereas in the south it is much thicker: 150 m–200 m. As was already stated, it is believed that it is thickest south of W. Ish-she.

As to the stratigraphical position of the Ein-Gev sandy rocks, the following explanation is proposed:

The brackwater series represent a shallow lagoonal inland ingression, into the already structurally depressed area, belonging in time to one of the Neogene mediterranean trangressions. How far NE its shores reached is not known. Picard (1943) assumes a connection between Hermon and Damascus basins with the Ein-Gev clastics. The latter are overlain by limnic-lacustrine series (*Dreissensia*) comparable with the freshwater series overlying the brackwater series in the west (W. Bira–Tiberias).

The Ein-Gev clastics are at least partly of marine origin (Avnimelech 1937, Cailleux 1948, Reiss — verbal communication), and its components of Nubian Sandstone origin (Vroman 1944), similar to the relatively thin sandstone of Tiberias. The latter is underlain by brackwater and overlain by freshwater series.

Farther south, the sandstone disappears altogether. Instead, the gypsum intervenes between the brackwater and freshwater series. This gypsum (2–10 m thick), as already mentioned, marks the closing of the temporary and weak connection with the sea. It represents a relict closed basin. Towards the south and SW (W. Ish-she), the otherwise pure gypsum banks pass into many intercalated gypsum-marl beds. The Tiberias sandstone in the north, therefore, is situated at the same position in the sequence as the gypsum more to the south. It must not however correspond in time to the latter.

The origin of the Ein-Gev sandstone and sand is to be looked for in the E and NE, where Nubian sandstone formations have already been exposed during this ingression. The shores of the diminishing lagoon became less and less sandy as they retreated south and southwest. The central part (i.e. W. Bira–Menahamiya with pure gypsum banks) became a closed lagoon while more to the SW the isolation was not yet completed (alternating Gypsum marl).

The freshwater sedimentation as well most probably did not develop simultaneously over all the area. It proceeded from north to south in the wake of the dying lagoon.

The Ein-Gev sandstone may therefore be regarded as an eastern shore facies of the Neogene lagoon, and the Tiberias sandstone as a regressive shore sandstone (Figure 16).

Neogene volcanic activity (v) may have played an important role in the sealing up of this basin.

The freshwater lacustrine beds (f) can be followed in the north and in the south alike. They have, on the whole, the same main characteristics all over the area; still some variations can be pointed out:

The platy chalk (f_1) in the area south of W. Fajjas is at most 35 m thick, whereas its northern equivalent is 58 m thick .The latter shows also more lithologic variations.

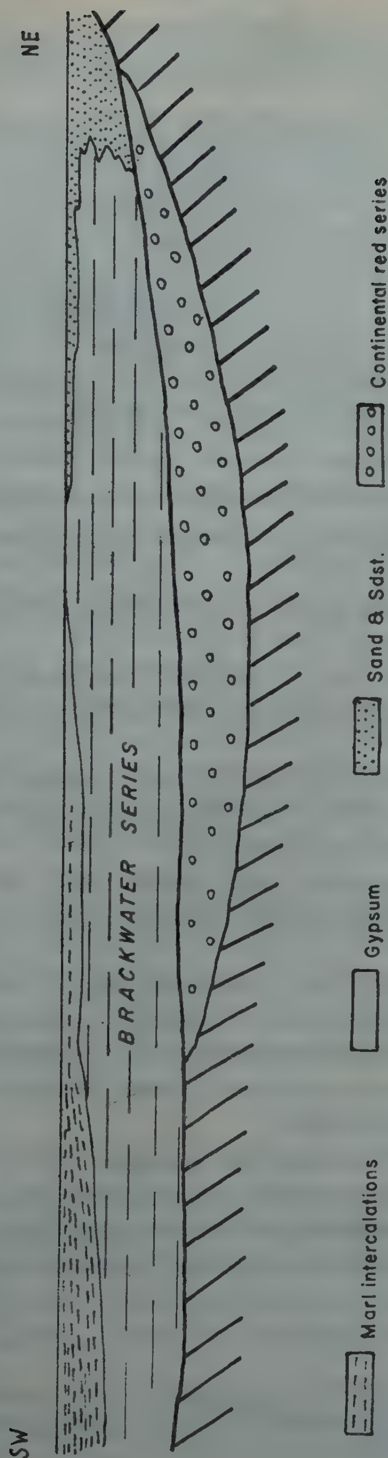


Figure 16
Schematic stratigraphical cross-section through the Neogene brackwater basin in the Central Jordan Valley.

The oolitic limestone, as well, is thicker in the north.

On an average, the total thickness of freshwater series in the north is about 130 m as compared to 50 m in the south.

As was already stated, the freshwater series with its endemic fauna and frequent lateral lithologic changes, represents certain environmental conditions within the depression, but can not be used as a definite stratigraphical time unit.

The correlation of the inland Neogene sediments, described in this paper, with the marine Neogene in the west was attempted by Picard (1943) and Bentor (1946), who correlate the freshwater series with the Astian marine transgression.

The author's opinion is that the correlation between the shallow marine lagoonal brackwater series (y) with its stratigraphical time equivalent in the west would provide the most reliable means for arriving at safer conclusions.

ON THE TECTONIC INTERPRETATION OF THE JORDAN VALLEY

Various tectonic interpretations of the Jordan Valley had been proposed since the middle of the last century.

1841, Leopold von Buch was the first to state that the faulting was the main factor in the creation of the valley.

The ideas of later geologists can be classified in three main groups*.

1. The existence of a single big normal master fault in the east (Lartet 1869, Huddleston 1885, Hull 1886).
2. The theory of two faults (eastern and western) caused by tension (ideal graben) was set forth by O. Fraas (1867), von Rath (1881), Suess (1891), Blanckenhorn (1914), Gregory (1921) and Picard (1931, 1932).
3. The tangential–compressional theory (ramp valley) put forward by Bailey Willis (1928) and others, assuming a lateral movement along thrust faults at deeper levels of the crust.

The present paper deals only with a small sector (20 km long) of the Jordan Valley and is confined to its western part only. It is, therefore, dangerous to make generalizations about the tectonics of the whole Dead Sea–Jordan Valley depression, based on local data. Nevertheless, some conclusions should be drawn about the structural evolution of the central Jordan Valley.

There is enough evidence to state that a negative movement started at least in Neogene times. This continuous sinking can be divided into two unequal periods: 1) the earlier and longer subsidence, without any conspicuous faulting in the upper levels of the crust; 2) a later and comparatively shorter period, representing the main faulting phase.

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* Since the presentation of the Hebrew text, the author has become acquainted with A. M Quennell's *Tectonics of the Dead Sea Rift*. Quennell assumes that the main tectonic element of the Dead Sea–Jordan Valley is a wrench fault.

Volcanic activity in all its phases is closely connected with the tectonic movements. There is a close relation between the intensity and nature of both. This relation is by no means simple. There is ample evidence that the regional volcanic activity, inside and outside the narrow tectonic valley, started contemporaneously with the first known tectonic movements of the Jordan depression, but this voclanism is not confined to this narrow belt and is well-developed far outside it.

Some of the previous workers in this area believed the presence of dykes inside the graben to be necessary to prove the tensional nature of the tectonic movements. At least in this part of the valley, no dykes have as yet been found.

As to the mechanism of the faulting; the area described in this work, situated at the western rim of the depression, is built of antithetically rotated, narrow, step-faulted en-échelon rows. It is believed that these faults (described in a former chapter) represent only superficial adjustments to the main tectonic element. These are border-faults (Randstoerungen) characteristic to many other tectonic depressions in the world, of a proved tensional nature. They probably do not reach the lowest levels of the crust and therefore must not necessarily be preferred by dykes.

The zone of the exposed border faults is here 3 km wide. Across this zone the average combined vertical displacement is only 500 m. There remain 4–5 km more across the valley floor to the eastern escarpment. Here the structure is concealed under a thick post-tectonic young cover. According to geophysical data this cover is a few thousand metres thick, and correspondingly the vertical displacement is probably of similar dimensions. If this is true, it would be difficult to imagine the presence of two so closely-spaced master faults all through the crust.

It should be added in support of this idea, that south of Beit-Shan, at W. Farah, the Jordan Valley is only 1–2 km wide.

The author's opinion is that the Jordan Valley has at its lower levels of the crust one main normal fault which bounds the eastern rim of the valley (Lartet 1869, Huddleston 1885, Hull 1886). The western rim is built up of antithetic border step faults.

Until more geological and geophysical data are available this assumption remains highly speculative.

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CLASSIFICATION AND NOMENCLATURE OF SOILS IN ISRAEL TAXONOMIC COMPARISON AND GENETIC RELATIONSHIP WITH SOILS FROM OTHER COUNTRIES

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ABSTRACT

The pedologic classification of Israel soils, as developed during the last 30 years by Reifenberg, Zohary, Ravikovitch and others, is reviewed and compared. Although the nomenclature has differed somewhat from author to author, the same 12–14 major genetic soil types have been generally recognised. Alluvial soils have been differentiated only in Strahorn's early survey, who used the system of soil series as a primary taxonomic unit.

From a comparative study of their morphological characteristics, the soils have been correlated with similar ones in the classification of Great Soil Groups as used in the United States and in Australia, and with Kubiena's systematics of European soils. Practically all of the Israel soils could be correlated with well established soil groups of various countries. Kubiena's system has been found particularly useful for the classification of hydromorphic and skeletal soils. Several changes in the present nomenclature have been suggested, to conform with international usage.

Some problems encountered in pedogenetic studies in the Eastern Mediterranean are discussed. Detailed profile studies in relation to local topographic and geomorphic conditions, supported by detailed mineralogical investigations, are urged.

THE AIMS AND SYSTEMS OF SOIL CLASSIFICATION

By soil classification we understand the arranging of soils into certain groups according to some characteristic properties. Several systems of classification, using various criteria of grouping, have been used in the past. Most of the schemes belong to one of two different lines of thought: the first, which may be called the empirical or technical approach, classifies soils according to one or several of its measurable and easily distinguishable features and properties, whereas the second, often called the genetic or functional system, aims to classify soils on the basis of the operating soil-forming processes as they are inferred from the morphology of the soil profile. A number of systems use multiple criteria and combinations of principles.

Systems of classification

In the technical systems of soil classification soils are grouped according to one or several of its characteristic features or properties, such as texture, clay composition, salinity, colour, etc. Any of the many properties of a soil can be used for this purpose, and various specialists are likely to choose quite different ones, according to their

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specific needs and interest. In fact, experience has shown that one of the greatest difficulties in applying such a system is in deciding which properties are important and of value for a particular objective.

Examples of purely technical systems of soil classification are those developed by soil conservationists for land use capability surveys, which consider a few selected properties considered of importance in soil conservation, or classifications based on textural properties of the soil commonly used by foundation and hydraulic engineers. Various empirical systems of soil classification and productivity rating have also been used in land evaluation for purposes of taxation.

All these systems do not consider the mode of origin of the soils and its natural qualities as a whole, nor the relationship among various kinds of soils. Thus such single purpose surveys and maps remain useful only as long as the selected properties on which the classification is based retain the same importance as when the original surveys were prepared. All too often it is found that characteristics which were thought to be of importance at one time become unimportant with increased knowledge or changes in technology.

In the genetic system of soil classification the soil is viewed as an anisotropic body occupying the land surface and is studied in relation to its geomorphic and climatic environment. Classification is based largely on inferred and assumed soil forming processes as they are reflected in the morphology of the profile. This approach was developed mainly by Russian soil workers towards the end of the last century. It requires a detailed study of the soil profiles in the field, and is supported by laboratory studies of soil formation processes. Each soil type is viewed as a dynamic body in the landscape, exhibiting breadth, width, as well as depth, and possessing a modal set of characteristics acquired during its development. A good example of this system is the classification as used in Australia (Stephens 1956).

Depth of the various horizons, their colour, texture, structure and composition are used for the identification of a soil. More recently also micromorphological examination of thin soil sections under the microscope has been recognised to render much information relevant to the mode of genesis (see Osmond 1958). Maps produced on the basis of soil profile examination are of a more fundamental character than special purpose maps, and serve as a basis for the utilization of soils for a wide variety of purposes and objectives (Stephens 1953, Soil Survey Manual 1951.)

The main handicap in the application of the genetic system of soil classification is our insufficient knowledge of the processes acting in soil formation, thus introducing an element of subjectivity in the definitions of genetic types. As a result the soils are classified in practice on the basis of properties which are considered genetically significant in the light of the present knowledge and concepts of soil formation, but which may well change in the future. In a way therefore, such a classification represents the state of our knowledge about the soil at a given moment.

An example of a property which was believed to have wide genetic implications,

but where subsequent knowledge invalidated its alleged general significance, is the chemical composition of the soil clays.

When it was appreciated that the colloidal fraction of the soil, or the weathering complex as it was called, was indicative of the direction of weathering, attempts were made to base a general classification on the silica-sesquioxide ratio ($SiO_2/Al_2O_3 + Fe_2O_3$) of the clay. Average ratios were obtained for the main soil groups of the world, and were then correlated with climatic characteristics (Reifenberg 1933, Crowther 1930). The significance of the ratio was however not always evident. When the subsequent development of X-ray diffraction techniques proved the crystalline character of soil clays, it became evident that because of the prevalence of isomorphous substitutions widely different clay mineral mixtures could possess the same silica-sesquioxide ratio. The attempt to correlate the SiO_2/R_2O_3 ratio with definite weathering stages or even specific clay minerals becomes thus quite unreliable, and has been abandoned as the basis for comparative regional development.

Many soil classification schemes base their grouping on the assumed environmental factors which have directed the process of soil formation (e.g. Vilenski 1925). The great value of this functional approach lies in the possible arrangement of soils into sequences, thus stressing their genetic relationship (Jenny 1941, 1946). Because of interdependence among the soil forming factors (e.g. climate and vegetation or parent material and topography) soil properties cannot usually be related to a definite conditioning factor and if uncritically applied the functional scheme becomes a classification of the external soil forming factors rather than of the soil.

The extreme logical systematization of the functional approach is Jenny's attempt of defining a soil in the form of a mathematical formula, expressing the functional relationship between a limited number of independent soil formimg factors, from which the soil properties would be predictable without requiring their determination in the field.

The concept that different combinations of soil forming factors and processes would result in implanting to the soil variable properties implies that an infinite number of possible soil types exists. In practice it is found necessary to limit the number of defined soil types and to group similar soils into larger units.

The genetic soil type, defined according to the inferred process of soil formation, implies a certain combination of soil forming factors. The reason why in the various soil classification schemes only certain combinations of soil forming processes and related environmental factors which have conditioned the soil properties are categorized and given specific names is a compromise dictated by motives of practicality. It is mainly because of this that all soil classification systems will remain incomplete and provisional. Any criteria we choose for grouping of the soils are of necessity subjective and suited to our own convenience, and cover only certain points of the whole spectrum of possible combinations of soil forming reactions and related environmental factors. For this reason a widest possible agreement in the classification

and nomenclature of soils is necessary, otherwise great danger exists that the inherent practical aspects of a genetic soil classification become unutilizable.

Problems of nomenclature

The aim of soil classification ,whether it makes use of the empiric, genetic or functional system, is to facilitate its study, use and identification. For the latter purpose soils are usually given names, whose purpose is to supply a means of referring to any defined kind of soil without having to indicate its characteristics or history. Soil scientists have often adopted local colloquial names, while other names again are derived from the colour of the soil. This however may lead to confusion when quite dissimilar soils exhibit the same colour. The term "terra rossa", for example, is applied by pedologists to characteristic clayey soils developed from hard limestone under the Mediterranean environment; others sometimes include under the name all reddish Mediterranean soils, irrespective of their origin. The considerable significance of conforming to agreed definitions and detailed type descriptions is thus readily comprehended. Modern soil surveys are in fact always accompanied by several detailed profile descriptions of typical soils from each group, and considerable standardization in the terminology and outline of the descriptions has been achieved, mainly through the influence of the American Soil Survey (Soil Survey Manual 1951).

General classification shemes

One of the most widely used genetic soil classification schemes is the system which has its origin in the work of Dokuchaiev and his associates in Russia*, and which has been subsequently modified and developed, particularly in the United States and in Australia**. The classification makes use of several levels of categories, usually termed — soil phase, type, series, family, great soil group, suborder and order. The classification aims to be morphological, guided by genetic principles and relationships; i.e. it is based on the appraisal of features found in the soil itself, which are chosen on the basis of assumed genetic significance. The colour, texture, structure, consistency and sequence of the various horizons in the profile are the main attributes used in characterizing a soil unit.

Experience has shown that at the level of the "great soil group" soils are reproducible over widely separated areas, and that this classification level can profitably be used in studies of comparative morphology and genetic relationships (Stephens 1950). Some 30–40 great soil groups are well established and defined at present, and the use of an accepted nomenclature is fairly consistent from continent to continent.

In detailed soil survey the primary taxonomic unit is almost universally the soil series, which are differentiated mainly on the basis of significant variations in the

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* For some recent Russian views on soil classification see Rozov (1957) and Basinski (1959).

** The current approach to soil classification in the United States is summarized in *Soil Science* 67, No. 2, 1949. More recently a revised system is being prepared and tentative drafts have been circulated. The system in use in Australia is described by Stephens (1954 and 1956).

morphological features of the soil profile. Many thousands of unique local soil series exist in the world, and this large number has been used by some in their criticism of the applicability of soil series classification. The local characteristic of the soil is generally manifested in designating the series by geographical names in conjunction with the name of the world group and the texture of the surface soil.

Soil family, the intermediate taxonomic unit between great soil group and soil series, is at present less well defined, and only tentative groupings of soil series have been made so far.

Based on his studies of European soils, Kubiena (1953) has recently devised and developed a detailed systematic classification scheme. The categories used are 40 global types (equivalent approximately to the great soil group), with a number of subtypes and varieties in each. Local forms of these types and varieties constitute the primary cartographic soil unit, corresponding to the American soil series. The higher categories are classes and the three divisions of sub-aqueous, semi-terrestrial and terrestrial soils. Altogether 173 different soil formations are systematically described and many of them illustrated in colours. The book is also provided with a number of dichotomous keys for the easy identification of unknown soils. Considerable significance is given to the identification of the humus form, and to the trend of soil development as mirrored in the nature of the soil profile*. The approach of Kubiena has already influenced soil studies in several countries, and the classification has also been successfully applied in the Mediterranean environment (Osmond 1955).

It is the object of this paper to apply these classification systems, which are in use in various countries, to the soil groups already recognized in Israel. For this reason a brief review of soil classification as used until now in Israel is necessary.

SOIL CLASSIFICATION IN ISRAEL

Modern soil studies in Palestine date back about 30 years, to the establishment of the Agricultural Experiment Station of the Jewish Agency, to the late Professor A. Reifenberg's researches at the Hebrew University, and to the invitation of the World Zionist Organization to A.T. Strahorn to make a reconnaissance survey of the soils of Palestine. Soil classification has been taken up by a number of investigators since, and various systems have been used, not always with full agreement among them.

Land use capability survey

An outstanding example of the purely empirical system of classification is the recently

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* Five general groups of soils are distinguished according to the nature of their profile, progressing from the simple to the more complex:

(A)C soils — Raw soils without a macroscopically distinguishable humus layer.

AC soils — With a distinct humus horizon, but without B horizon.

A(B)C soils — With pronounced B horizon, which however is not a real illuvial horizon. Its origin is due to deep reaching weathering under well drained conditions.

ABC soils — With illuvial B-horizon.

B/ABC soils — Soils with strong enrichment of illuvial substances transported to the surface.

completed land use capability survey by the Soil Conservation Service of the Ministry of Agriculture (Gil and Rosensaft 1955). The survey was based upon and concerned only with six easily distinguishable soil characteristics and land features: texture, stoniness, colour and depth of soil, slope, and erosion class. The aim was to map land types for use in soil conservation and for land use capability rating. No attempt was made to determine all characteristics of the soil, its relationship to the neighbouring or other soils, or the relationship between each soil and the factors of its environment.

This detailed and extensive survey is a great advance over previous ones, when on a number of occasions surveys preliminary to colonization were limited to textural classification, sometimes supplemented by a salinity evaluation of the top soil. The classification has been reviewed by Lowdermilk, Gil and Rosensaft (1953), and the reader is referred to this publication for details. It will not be evaluated further in the present study, which is mainly concerned with the application of the genetic classification systems, and only the map of soil types, which accompanies the published report, will be considered.

Pedologic surveys and classifications

The first modern soil survey of Palestine was made in 1927–28 by A.T. Strahorn from the American Bureau of Soils on behalf of the World Zionist Organization. Strahorn surveyed almost 4.9 million dunam of the lowlands of Palestine. Maps on a scale 1:40,000 and 1:63,360 were used in the field, and the data were then assembled on a 1:250,000 map*. He used the American system of soil series as the primary unit of soil classification and for mapping purposes, and in the published report 26 soil series, which were given geographical names, are defined and distinguished. Broader divisions used are based on geological characteristics of the landscape and include a) soils formed in situ (4 series), b) soils formed on older alluvium (10 series), c) soils formed on recent alluvium (7 series), and d) soils formed from windblown material (4 series). One series is distinguished as being of mixed formation. The agricultural use and adaptation of the various soil series are also discussed.

From the report it is evident that Strahorn recognized the considerable influence of geomorphological features on the differentiation of the soil landscape, and from many viewpoints his classification and descriptions are strikingly up to date. Unfortunately it appears that his report has received only little attention from subsequent workers.

Reifenberg studied in detail the chemical properties of most soil types occurring in Palestine, and compared their composition to that of the subjacent rocks. The researches are ably summarized in his book "Soils of Palestine" (1947, 2nd ed.). The book includes also a schematic soil map (ca. 1:1.6 million), which leans heavily on the geological map of Blake. Eleven major soil types and a few sub-types are distinguished

* The published report (Strahorn 1928) does not include the maps, of which apparently only 3 copies were prepared. One set is stored at the Agricultural Research Station, Rehovoth, and the writer is indebted to Prof. S. Ravikovitch for the opportunity to examine them. In condensed form the report was published by Strahorn in *Geographical Reviews* (1929).

and described. In combination with the parent material he considered climate as the dominant factor in the differentiation of the soils, and they were therefore grouped into 4 climatic zones, which are differentiated by specific rain factors*.

Zohary, also of the Hebrew University, studied the relations between the vegetation and the various soil formations, and based upon field reconnaissance he published a generalized soil map** on a scale of 1: 600,000 (1942 and 1947). Zohary's 11 soil groups of "varieties of common origin" are sub-categories of the three phytogeographic zones of Eig, and thus essentially characterized climatically. Within each zone the soil differentiation is conditioned mainly by petrographical and topographical features. The nomenclature used varies somewhat from that of Reifenberg, in particular in the rendzina group, which was introduced into local nomenclature by Zohary, but was not accepted by Reifenberg.

Accompanying its land use capability survey the Soil Conservation Service also published a soil type map, 1: 500,000 on which 13 soil types are distinguished (Gil and Rosensaft 1955). The map is not accompanied by any explanatory text, and it is thus not known what criteria were used for establishing boundaries between soil types. The land classification itself was to a great extent based on air photographs and checked in the field by a number of teams. Judging from the resources available the map could be more precise than the previously published ones, but its real value cannot be ascertained until more descriptive information is available. The nomenclature used is very similar to Zohary's.

Ravikovitch, at the Agricultural Experiment Station, published a number of surveys for several physiographic regions, accompanied by maps (Sharon and Shephela ca. 1:400,000, Northern Negev ca. 1:500,000, Huleh Valley ca. 1:90,000), and discussed also in a general paper the soils of the country as a whole (Ravikovitch 1944, 1948, 1950, 1953). Within each region the soils are differentiated mainly by texture and salinity as determined by numerous laboratory analyses. The boundaries on the maps were then drawn by interpolation from these laboratory data, which leaves the maps thus produced open to serious errors. More recently a reconnaissance survey and map of desert soils were made by the staff of the station (Ravikovitch, Pines and Dan 1956).

Comparison of classification and nomenclature

Comparing the soil maps prepared and the classification used by the various workers, the rather good agreement between them is more striking than the differences.

The nomenclature used for the different soil types is compared in Table 1. Some of the names used correspond to international usage, others however are new and local and were not always chosen with equal luck or consistency. Connotative names

* For a complete bibliography of Reifenberg's work see *Israel Expl. Jour.*, 1954, **4**, 143–149.

** The map has been subsequently extended in his book "Geobotany" (Sifriat Hapoalim, 1955, in Hebrew) and in the map published in "Atlas of Israel" to include the soils of the Negev.

TABLE I

A taxonomic comparison of soil groups recognized in Israel, compared with classifications used in other countries

Nomenclature as used by				Correlative according to	
Reifenberg	Zohary	Ravikovitch	Soil Conservation Service	Great Soil Group Classification*	Kubiena's Scheme
Terra rossa	Terra rossa	Terra rossa	Terra rossa	Terra rossa	Terra rossa
Medit. red earth on igneous rock	Basalt soil	Basaltic soil	Basaltic soil	Chocolate soil	Meridional Braunerde
Red sandy soil	Red sandy clay soil	Brown-red sandy soil	Soils of loamy sand, sandy loam and sandstone	Hamra	Dry Rotlehm
Nazaz	Nazaz	Nazaz (degraded stage)	〃	Hamra with pseudogley horizon	Bleached Rotlehm ?
Kurkar soil	Kurkar or calcareous sandstone soil	——	〃	Rendzina	Pararendzina
——	Dark rendzina	Brown Mediterranean	Rendzina soil	Rendzina	Xerorendzina
Mountain marl soil	Light coloured rendzina	Mountain rendzina	Gray limestone soil	Grey calcareous soil (A)	Chalk syrozem (chalk raw soil)
Lisan marl soil	Lisan marl (non-saline)	Grey calcareous soil Valley rendzina	Marl soil	Grey and brown soils of heavy texture (A)	Calcareous warp soil (chalk rambla)
Alluvial soil	Alluvial soils	Alluvial soil	Alluvial soils	Alluvial soils	Various types, e.g. Red warp soil
Aclimatic black earth	〃	Alluvial hydromorphic soil	Marshy alluvial soils	Humic gley (US) Calc-gley (E) Groundwater rendzina (A)	Chalk marsh Mull gley Smonitza
Peat	〃	Peat soil	〃	Fenpeat (A)	Calcareous eutrophic anmoor
Mediterranean steppe soil	〃	Brown alluvial	Alluvial soils	Sierozem Calsisol (US) (in part)	Burozem (light brown desert-steppe soil)
Loess soil	Loess	Loess and loess-like soils	Loess soil	Sierozem	Loess sierozem or syrozem (grey desert steppe soil)
Sandy loess	Sandy loess	Brownish-yellow sandy soil	Sandy loess soil	〃	〃
Semidesert and desert soils	Calcareous steppe Hammada	Desert brown and grey mountain soils Hammada	Limestone soils covered with loess	Desert soils Regosol	Dry desert raw soil (yerma) Hammada yerma
Saline soils (white alkali)	Saline soils a) automorphous b) hydromorphous	Solonchak and solonetzic soils Hydromorphic saline soils	Salty and marshy alluvial soils	Solonchak	Solonchak
Dune sands	Sand dunes	Sand dunes	Sand dunes	Aeolian sand (A) Dry sands (US)	——

* Includes proposed classification and correlatives in US — United States, A — Australia, E — England.

have been generally preferred, and only Strahorn used local geographic names to designate his soil series. A number of these can be readily identified with the connotative names, and his classification differs from the others mainly by being more detailed with respect to the various alluvial soils. (Not included in Table 1.)

It is evident that the same 12–15 genetic soil groups have been generally recognized, and considering that often the type definitions have not been too detailed, and that profile descriptions were used only sporadically, the agreement is certainly the more astonishing. It seems to suggest strongly that because of the sparse vegetation throughout most of the year, and because of the strong and often dominant influence of the lithologic and geomorphic factors, in addition to the climatic influence on soil formation, the boundaries between the major soil units are fairly sharply defined and easily distinguishable. Indeed, even an untrained observer is struck by the large differences in the character of the soils when one travels from the Galilee to the Negev, or from the Coastal Plain to the Jordan Valley.

It remains to be seen whether the same groups, so easily distinguishable in Israel, can be identified and correlated at the same level of classification with similar soils in world classification schemes*, or whether additional groups are required to accomodate them.

THE POSITION OF ISRAEL SOILS IN WORLD CLASSIFICATION SCHEMES

In the following discussion the soils have been grouped into a number of convenient categories, which however do not intend to imply *a priori* any genetic or other relationship among them.

Mediterranean red soils

Reifenberg (1949) deplored the fact that few classification schemes give sufficient emphasis to the particular characteristics of Mediterranean red soils. He suggested that these soils should be treated as a separate unit, with three subdivisions, based on the conditioning influence of the parent material: a) on limestone — terra rossa; b) on igneous rock — Mediterranean red earth; c) on coastal sand formations — Mediterranean red sands.

Terra rossa soils, originating from hard limestone or dolomite are widespread in all Mediterranean countries. They are fairly extensive in southern Australia, and soils of a somewhat similar morphology have also been mapped in the semiarid regions of the south-western United States. Genetically the terra rossa soil is believed to be related to the brown forest soils of America, and to the red and brown calcareous

* The author has not visited all of the localities abroad mentioned in the following description. The comparison of Israel soils with their counterparts in other countries is mainly based on a detailed study of the literature, profile descriptions, colour photographs and illustrations, and on discussions with colleagues. The illustrated books of Kubiena (1953) and of Stephens (1956) were of great help and repeated reference will be made to them. The recent extensive use of colour photographs or drawings accompanying soil surveys and soil geographical studies has been of considerable help. It is impossible to acknowledge all the sources which have been consulted; the important ones, however, will be duly quoted.

soils of Britain, these being thought to be a simple replacement of terra rossa under a more humid climate.

The uncertainty in placing the terra rossa in its proper place in the genetic classification scheme stems largely from the fact that it is both related to climate, and thus a climatogenic or zonal soil, and also to a certain kind of rock, i.e. it is calcimorphic, and in that sense an intrazonal soil. Its standing as a separate great soil group is however rarely questioned, and the definitions as given be Reifenberg or Kubiena are generally accepted.

The rather heavy clay soils of the Lower Galilee, with A(B)C profiles, derived from basalt, seem to have many properties in common with the basalt soils of N. S. Wales, Australia, which have been recently described by Hallsworth *et al.* (1952), Costin (1955). These authors consider them to be sufficiently different from related brown earth to merit their separation as a distinct great soil group — the *chocolate soil.* They are mainly characterized by a heavier texture, without a distinct horizon differentiation, granular to blocky structure, and dominance of montmorillonite in the clay, with the therewith associated higher exchange capacity. All of these characteristics are in good agreement with basalt soils in Israel. Like terra rossa they exhibit a shallow, humus deficient A-horizon, followed by a moderately thick (B) horizon, which usually lies directly on the C-horizon. Climatically the Australian chocolate soils are considered intermediate between the associated chernozem and krasnozem (tropical red loams), though they may occur close together. It may well be that in the Galilee too, in areas of increased intensity of weathering, transitional krasnozems will be recognized.

Soils similar to the *red sandy soil* of the Coastal Plain are known in the area of coastal limestones (aeolinite) in southern Australia (Crocker 1946, Fairbridge and Teichert 1953) ,where they however are not differentiated from terra rossa. Both in Israel and in Australia red sands are also found as relict soil horizons (palaeosols) intercalated with the aeolian dune rock. The genesis of the red sandy soil is entirely different from that of terra rossa, and according to Rim (1951a, 1951b) they have been formed by winnowing of the coastal dunes, which is accompanied by a simultaneous mineralogical sorting of the sand grains. They develop directly from the non-calcareous portion of the stabilized dune (Figure 1a, 1b), but also where conditions are favourable, after decalcification of the associated porous kurkar rock. Whereas the clay minerals of the terra rossa soil are largely residual and inherited from the parent limestone, the small amount of kaolinitic clay present in the red sandy soils is mainly the result of weathering and authigenesis within the soil (Yaalon 1955). The characteristic yellowish red colour (mostly 5YR 5/8)* of the sands is due to a thin coating of the quartz grains by colloidal iron oxides (Ravikovitch 1950).

Weathering and hydrolysis of the heavy minerals in humid depressions between dunes apparently leads to the formation of characteristic uncemented hardpans, which when buried by the red sand obstruct root penetration and normal moisture movement. These hardpans are locally called *nazaz*. Surface conditions do not offer

* Munsell soil colour notation.

any indication of the presence of the hardpan, except that it is found more frequently and better developed in depressions between dunes, rather than in ridges. The large lateral variations in textural profiles render it unlikely that illuviation is the main process in nazaz formation as suggested by Ravikovitch (1935). Its characteristic orange, reddish-brown and grey mottling, and the relatively high content of reduced iron are clear indications of the reducing environment in waterlogged conditions, resulting in the formation of gley-like features (Lachover and Fenster 1952). It seems that the nazaz soil is to be recognized as a sub-group of the red sandy soil, exhibiting pseudogley features.

It may well be that a number of other subgroups or varieties could be distinguished, if, for example, the age of the dune generations could be determined from their heavy mineral composition. The rate of formation of these soils is comparatively rapid, probably no more than a score hundred years, and is subject to the perennial evolution cycles of accumulation, stabilization and erosion (Rim 1950, 1955).

Besides the widely different genetic history and textural composition, red sands and terra rossa are easily distinguished by their position in the landscape and by the vegetation which develops on them. Typical terra rossa in Israel is found only in the highlands and associated with a karst landscape. The soil cover is very irregular and stony, and deeper soil accumulations are only found in depressions and on flattened slopes. Much of the soil has been eroded and deposited in the flood plains where it

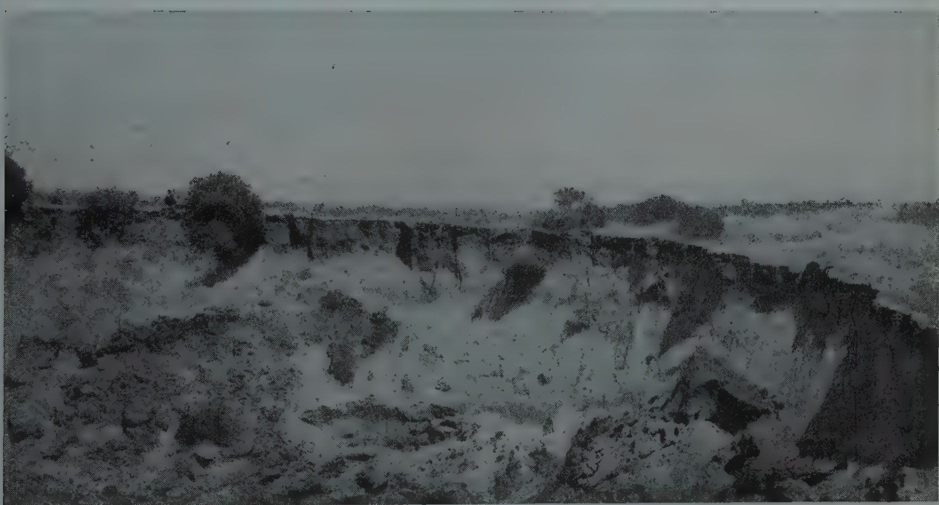

Figure 1a

A young yellowish red (5YR 5/8) sandy hamra soil developed from yellow (10YR 7/6) unconsolidated non-calcareous dune sand. There is a thin (less than 2 cm), brown, organic matter rich surface layer, and the thickness of the reddish brown to yellowish red profile is 50 to 80 cm. More mature and cultivated hamra soils exhibit a fairly uniform yellowish red colour several meters deep. (Crossroad Beit Lid — Beit Itzhak)

Figure 1b

A yellowish red (5YR 5/8), sandy loam, hamra soil. The top 25 cm are somewhat darker because of organic matter enrichment, and the subsoil below the depth of 70 cm is somewhat more compact and exhibits greyish mottling and pseudogley features. Roots penetrate through the whole profile, largely between fine cracks of the weakly developed columnar structure. This was a heavily irrigated garden soil. (Pardess Hanna)

forms deep alluvial deposits. (These should then be classified as red warp soils; cf. chapter on alluvial soils, p. 112.)

The red sands on the other hand are limited to the young coastal plain, exhibiting a moderate, gently undulating relief, dissected only by river channels and interspersed with belts of hillocks parallel to the coast, which easily recall sand dunes. Nazaz hardpans, pararendzina soils and shifting sand dunes occur in association with the red sands.

The characteristic of red sandy soils as described above are deemed sufficiently different from terra rossa and important enough to separate them validly as a separate great soil group. In Israel they are locally known as *hamra*, and it is suggested that this name be adopted for the designation of the great soil group. The following definition is tentatively offered: Hamra is a yellowish red sandy loam or loamy sand, associated with dune sand and calcareous aeolian sandstone formations formed on coastal plains under an intermittently dry and humid climate. The soil is decalcified, loose and friable, and generally without distinct pedogenetic textural horizons. Clay

enriched hardpans, generally mottled due to hydromorphic and reducing conditions, are sometimes encountered.

Although so far the red sands have been reported only from the Eastern Mediterranean and from southern Australia, there is reason to believe that they will be located in other coastal areas with similar morphological and climatic conditions.

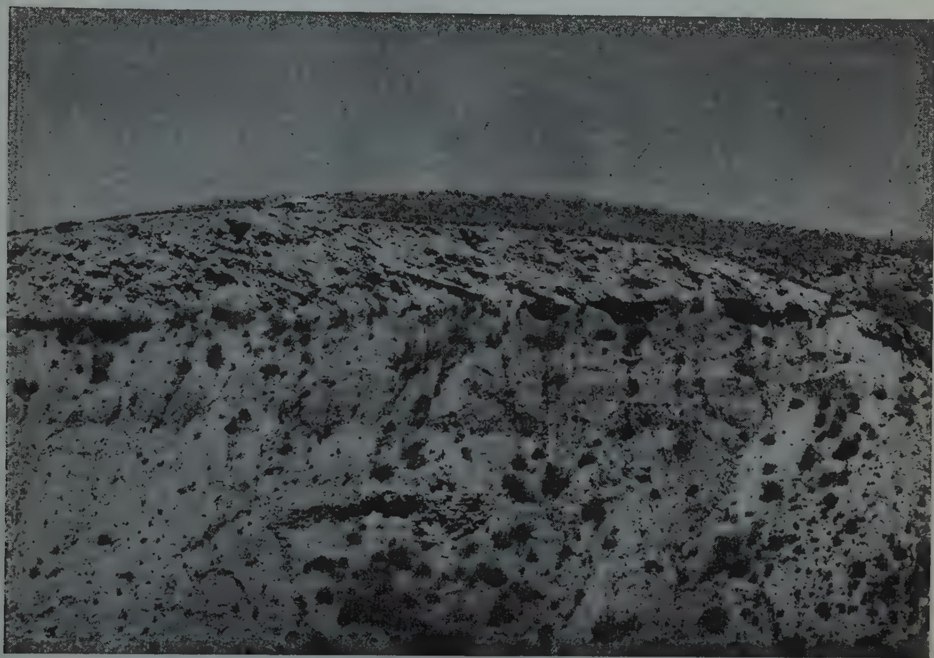

Figure 2
Stratification of aeolian deposits on the Coastal Plain. A cap of light gray to white (10YR 7–8/2) kurkar rock (maximum thickness ca. 7 m), overlying a 5 to 7 m thick layer of yellowish red (5YR 5/8) hamra, gradually changing into loose yellow non-calcareous sand, overlying another layer of kurkar rock.

Note the dune-like structure and bedding of the kurkar rock, upon which there is developed a shallow (less than 20 cm), brown (10YR 5/3), compact calcareous, sandy pararendzina soil. The second layer of kurkar rock can be seen exposed at the lower centre of the picture. The hamra layer in the middle is a fossil soil, but according to Rim (1951) it may also represent the lower non-calcareous part of one large dune. Note that even the steep colluvial slopes of hamra are partly covered with vegetation. The uncultivated pararendzina is sparsely vegetated by a few plant species only. (Beit Elazri on Gedera — Givat Brenner road)

Recapitulating, it would seem that all three major groups of red Mediterranean soils are genetically sufficiently different to be recognized as separate great soil groups. Terra rossa, owing to the dominant influence of the parent material on its genesis, is often classified with the intrazonal calcimorphic soils. Where such a grouping of the genetic soil groups is used, Reifenberg's contention of the misrepresentation of Mediterranean soils, and his suggestion to treat them as a special zonal suborder,

seem appropriate. However, as the shortcomings of the zonality concept are being better appreciated, other criteria for the grouping of great soil groups are being sought. For instance in Stephens' classification scheme for Australian soils, suborders are differentiated according to morphological characteristics. In this classification scheme all Mediterranean red soils would be sufficiently well represented by the suborder of acid to neutral soils, lacking pronounced eluviation of clay. Russian pedologists prefer to group genetic soil types (equivalent to great soil groups) into suborders according to the direction of soil formation processes, and the Mediterranean red soils would seem to belong to the series of eluvial-xeromorphic soils.

In Kubiena's classification terra rossa is discussed in considerable detail, and several varieties are recognised. It is classified as a subtype and forms together with terra fusca the global type (equivalent to great soil group) of *terrae calxis*, thus stressing its calcimorphic origin. The chocolate (basaltic) soil can be at best identified as *meridional braunerde*, and hamra (red sand) as *dry rotlehm*, both groups being classified as varieties within the global type of braunerde and rotlehm respectively. Kubiena's (p. 228) identification of the nazaz as bleached rotlehm cannot be accepted as long as there is serious doubt about the alleged process of illuviation.

Rendzina-like soils

It is generally claimed among pedologists and in many soil text-books that soft (i.e. porous) limestones produce rendzinas, whereas hard limestones give rise to terra rossa. The relationship, however, is by no means as simple as that, and other factors, e.g. variations in the mineralogical composition of the non-calcareous residue seem to influence the development of soils on limestones (Yaalon 1955a). Slow drainage is another important factor leading to the development of black or dark grey limestone soils, and a catenary or sequence relationship between rendzina and terra rossa has also been claimed to exist.

Zohary was the first to apply the term *rendzina* to the grey and black soils associated with soft limestone in parts of the Carmel plateau and in the Lower Galilee, while Reifenberg was reluctant to use this classification. However, these AC soils being typically shallow, with good crumb structure, calcareous, medium to heavy textured, containing montmorillonite or palygorskite as the dominant clay mineral, and overlying a porous limestone without exhibiting a significant profile development, seem to have all the main characteristics of the continental rendzina and justify their classification as such (Figure 3). To stress that the climate under which these soils were developed is different from that for the humid temperate rendzina soils, the author has previously added the prefix Mediterranean (1954). The designation *xerorendzina* used by Kubiena (p. 189) for rendzina soils occuring in the mountains of dry regions, and recognized by him as a separate subtype of the global type Eurendzina, is probably equally if not more appropriate.

Varieties belonging to the xerorendzina subtype are developed on travertines in the Beisan Valley, and possibly some brownish ones which have formed upon weathering

Figure 3
A rendzina soil developed on porous Eocene chalk. Note the well developed granular structure of the grey brown (10YR 5/2), calcareous clay soil and the sharp transition to the bedrock. (Mishmar Haemek)

of *nari* (lime crust) should also be included. Other, less developed soils associated with nari, can be classified according to Kubiena (p. 157) as *lime crust yerma.*

The formation of the various rendzina soils in the Mediterranean environment needs much additional study. In particular the role of the clay mineral palygorskite, which is often found in association with montmorillonite in the Eocene and Senonian limestone, but which is easily weathered and altered, needs clarification.

The highly calcareous shallow grey to grey-brown loamy sands or sandy loams of the Coastal Plain, developed from *kurkar* (cemented calcareous sandstone), seem to have affinities with the dark grey calcareous soil formed on aeolonite and travertine in southern Australia (Crocker 1946) where such soils are classified as rendzina. The kurkar soil in Israel occupies a series of hillocks and ridges parallel to the coast,

exhibiting a rather rugged topography. Due to erosion and uneven weathering of the laminated sandstone the soil cover is not uniform, but of varying depth even within short distances. The shallow A-horizon usually contains variable amounts of sharply angular fragments of kurkar rock, and passes without transition into the C-horizon (Figure 2). They are not of great value agriculturally, and haven't been studied in any great detail as yet. Vegetationally they are distinct from the rendzina of the mountain region, and also from the surrounding hamra. On generalized maps they do not appear as a separate unit due to their occurrence as a complex with the genetically related hamra. If the calcium carbonate becomes completely leached out, the hydrolysis of the iron containing minerals may convert the material into a hamra; integrades between these two groups are thus also to be found. Kubiena (p. 191) coined for such soils the term *pararendzina*, recognizing it as a special global type, and this designation appears to be the most suited for the present.

Light coloured calcareous soils of the steppe region

Next to the red and reddish soils only the light coloured grey and greyish brown calcareous soils impress their character strongly upon the Israel landscape, especially in the semiarid and arid parts of the country. They rarely show any distinct profile development and the high content of lime is practically always inherited from the parent material. Often these soils are best characterized as immature, not because of the length of time the pedogenic factors have acted upon them, but because they have left little mark on them and mostly have not succeeded in obliterating the characteristic properties and nature of the parent material. The imprint of the parent material and the local geomorphic history is therefore strong. Obviously such soils are not readily subject to a pedogenetic classification, and it is also with these soils that we find the classification in use in Israel at present to be least satisfactory. Lisan marl and loess, for example, are essentially parent material designations rather than soil names, and soil evolution on these materials may differ according to the prevailing environmental conditions.

The shallow, grey highly calcareous (A)C soils, occurring in the mountain regions over a marly friable limestone have been named *mountain marl* by Reifenberg. Such soils are found both in the humid regions of the Galilee and in the arid Judean foothills; their development appears therefore to be conditioned by the physical properties of the parent rock and by its mineralogical composition. Mountain marl does not seem very satisfactory as a soil name. Zohary, following Miklaszewski (1924), calls them *light rendzina*. This term, however, has not found general acceptance, neither here nor abroad, e.g. in France or North Africa where such soils are also common. In Australia similar soils appear to be classified as grey calcareous soil. According to Kubiena's classification these soils can be identified as *chalk syrozem* (chalk raw soil), which is a subtype of the global type syrozem (raw soils) of the temperate zones. Kubiena mentions white rendzina as a synonym for his term, thus

in fact confirming Zohary's terminology. Chalk or *marl syrozem* is a suitable connotative name, and it is suggested that it be adopted.

As a variety of the chalk syrozem Kubiena recognizes *loess syrozem* (loess raw soil), a term which seems appropriate for the loessial soils of the arid Northern Negev. The more sandy variety can then be called *sandy loess syrozem*. It is well known that in humid temperate regions loess serves as parent material for a variety of important soil types. In Israel the loess remained largely in its raw state and soil evolution processes have not left any visible marks in its morphology, even though evidence of chemical processes taking place has been obtained (Yaalon 1955b). One reason for the weak morphological development is the fact that aggradation is still active, and that a constant shifting of the surface is taking place. Only where aggradation is slow can profile development be observed. Under the prevailing arid conditions they seem to develop into *sierozem* (grey desert steppe soil), which occur extensively in Russia. In fact Rozanov (1952) claims that a loess formation and sierozem formation proceed together. Sierozem are recognized as a great soil group both in the American and in Kubiena's classification scheme.

Northward of the loess sierozem, in the semiarid parts of the Shephela Pleshet, we find reddish-brown to brown calcareous silty clay loam or silty clay soils, which have been called *Mediterranean steppe soil* by Reifenberg. Other investigators mapped them as alluvial and considered them as being formed from a mixture of loess, sand and alluvial clay. The writer has accumulated evidence that their evolution is similar to that of loess and that the clay was deposited with the silt. A similar deposition of aeolian clay on the fringe of the desert steppe has been described from Australia (Butler 1956). In these AC soils leaching is more advanced than in the loess sierozem soils, and is probably responsible for the brownish colour. This and the considerably higher content of aeolian clay are the main properties differentiating them from the neighbouring silty loess of the Northern Negev.

Though there is a definite leaching of carbonates, a lime accumulation zone is not always visibly present. Its stratigraphic position in the soil profile, the degree of carbonation and distribution of carbonates through the profile is not fixed, but subject to readjustment to a changing environment. Typically the carbonates are precipitated at or near the depth of rainfall penetration and are present as soft irregular masses dispersed through the silt (Figure 4). Sometimes hard calcareous nodules are found. Clay movement is not apparent.

Reifenberg, who used the name Mediterranean steppe for these soils, recognized similar soils on the fringe of the Syrian desert (1952). Muir (1951) prefers to call them *grey and red-brown steppe soils*. Ecologists are, however, reluctant to use the designation steppe for this region which is still greatly influenced by the Mediterranean seasonal moisture regime, though the term is commonly applied to semiarid regions on the fringe of hot deserts.

The Mediterranean steppe soils show only slight resemblance to the classical chestnut or prairie soils of other countries, which are considered to be typically

Figure 4
A sierozem soil of the Shephelat Pleshet, developed from pale brown to brown (10YR 6–5/3) clayey loess with additions of alluvial material. The profile is strongly calcareous right to the surface and usually shows little textural or colour differentiation with depth except for the formation of the characteristic irregular soft calcareous concretions in the subsoil. In this profile the lime accumulation zone is at a depth of 25 to 85 cm, but its position in the profile varies depending on the depositional and erosional history of the soil. Frequently the subsoil exhibits a weak columnar structure. (Kiriat Gat to Mishmar Hanegev area)

representative soils of semiarid environments. They are possibly intermediate between the sierozem and chestnut soils, and the present schemes fail to provide a suitable great soil group for their classification*. Following the Russian classification they would most likely be called simply sierozem. Wherever the calcium carbonate accumulation horizon is sufficiently distinct they could be appropriately classified by the recently introduced term *calcisol* (Harper 1957).

Applying Kubiena's system leads us to classify them as belonging to the global type of *burozem* (brown desert steppe soil). A few varieties, mainly saline, are recorded, but none quite suited for the local type. The general variation of these soils within the landscape is duly noted by Kubiena, but his classification too fails to provide a suitable place for these special soils. Since one of the main differentiating characteristics is the lime content right up to the surface, the prefix calcareous to whatever name is adopted seems desirable.

The basin soils of the Upper Jordan Valley and Beisan, formed on the lacustrine Lisan Marl deposits, possess certain morphological and mineralogical characteristics in common with the sierozem and burozem of the Northern Negev. They differ by being of heavier texture (clay loams), darker as a result of a higher content of organic matter, more compact especially in the subsoil, and in showing influence of occasional hydromorphic conditions. They tend towards an A(B)C-profile, although AC soils predominate. Their nearest genetic correlative in the Australian scheme are the *grey and brown soils of heavy texture*, which are defined as essentially weakly hydromorphic and occasionally halomorphic soils of semiarid regions, which owe their origin to fine-textured deposits of alluvial plains, occasionally flooded and waterlogged, without significant leaching. However, in contrast to our soils, the Australian soils never seem to be highly calcareous and only exhibit a weak calcareous illuvial horizon.

The name *warp soil*, a term originally coined in England, where it refers to river sediment and alluvial deposit, generally calcareous and deposited by flooding on land adjacent to the river (Heatcote 1951), has been adopted by Kubiena for a number of different soils. Occurring in the flats of streams and rivers, and derived from their deposits, they may be temporarily flooded, but show no signs of gleying in their profile. They are grouped with the semi-terrestrial soils, but beyond the influence of a high water table they have the characteristics of normal terrestrial soils. Soils without a distinguishable humus horizon are called *raw warp soil*, and other suitable prefixes are used for those with land humus formation.

Although the Lisan Marl is predominantly a young lacustrine deposit, the dynamics and constitution of its derived soils seems sufficiently close to Kubiena's definition of warp soils to classify them as such. In most places their development is definitely

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* It is interesting to note in this connection that also the chestnut brown soils of the Mediterranean region, transitional between the Mediterranean and the forest climax, are believed to be sufficiently different from other brown soils to require separate great soil group status; cf. Gerasimov, I.P., 1954, Les sols marrons des regions Mediterrannéennes. *Commun. V. Cong. Intern. Sci. Sol.*, 40 pp.

influenced by impeded drainage, and owing to their high lime content they are aptly named *calcareous warp soil*, ranging in development from raw warp to anmoor warp.

Hydromorphic soils

Several small areas of hydromorphic, rather deep, calcareous soils, which Reifenberg considered to be *aclimatic black earth* (chernozem), are to be found in the Coastal Plain. They are dark, of medium texture, relatively high in organic matter, and usually formed largely from calcareous alluvial and aeolian material. Generally waterlogged during the rainy season, they develop a gley horizon coinciding with the actual water table. The organic matter content is distinctly higher than in tropical black soils (regur, black cotton, margalitic, grumusol, cf. Oak and Thorp 1951). In common with most black soils montmorillonite is the dominant mineral in the clay fraction. The Hule lake soils (Ravikovitch 1948) are of similar origin.

Stephens (1950) suggests that under hydromorphic conditions the catenary associates of rendzina are ground-water table rendzina, fen and fen peats, citing examples from Australia. In Britain (Avery 1956) poorly drained soils derived from highly calcareous clay are classified as grey calcareous soils with gleying, *calc-gley* for short, and calcareous soils affected by a high water table or by lateral seepage as ground-water rendzina. Both are recognized as separate groups at the same level as the related rendzina. In the U.S. classification the nearest correlative would be *humic gley* or half bog soil, but the Israel soils have a number of characteristics distinct from these soils. It would seem that the black hydromorphic soils of the former Kabbara swamps, of Nahal Poles, Nahal Alexander, and the lake Hule soils, have genetical and morphological affinities with all these groups, and that they are best classified as members of a major group of calcareous hydromorphic soils, grading both towards organic and gley soils. The term *humic calc-gley* is tentatively suggested as the most appropriate name indicating this relationship.

Kubiena's systematics is more detailed and depends partly on the humus form. While still largely waterlogged they would be classified with the class of *anmoor-like* soils. These are grouped into the global types anmoor and marsh, depending on whether the soils are inland or coastal formation. The subtype designations *calcareous eutrophic anmoor* and *chalk marsh* would then apply to the lake Hule soils and black coastal soils respectively. On drying out or following drainage the anmoor changes into terrestrial humus forms, and the soils could then be classified as *mull gley* or *smonitza**.

Halomorphic soils

Halomorphic soils in Israel occur in several smaller areas on the Coastal Plain, where a high water table of saline ground water influences the pedogenic processes. In the

* The stability of organic matter in calcareous soils under a hot dry climate has been the subject of some controversy. It would seem that drained areas of the coastal marshes and the drained swamps of Hule now offer a good opportunity to study this problem.

arid and semiarid soils of the Negev excess salt has accumulated in several places and may be of oceanic aeolian origin, the accumulation having been locally favoured by suitable relief and by the high evaporation rate. In a few salines accumulation is due to closed drainage. In the Jordan Valley salinity is associated with the lacustrine Lisan Marl, which contains some more or less saline strata. Where such strata are exposed by erosion or reached by ground water, the inherent salinity of the soil becomes a significant factor in determining the soil characteristics.

In all these cases the salinity is due to sodium chloride, occasionally also due to calcium sulphate. The soils generally do not exhibit any marked horizon development or differentiation, consequently it seems proper to consider them as belonging to the great soil group of *solonchak soils*, and they have also been classified as such in the past. Where the saline character is less pronounced it suffices to add the term as prefix to the regular designation, e.g. solonchak sierozem, etc.

No naturally developed solonetz soils have been described or are known to exist in this country, even though man-made alkali soils akin to solonetz are likely to develop as a result of improper methods of irrigation. A relatively high proportion of exchangeable magnesium and/or sodium is found in a number of soils in the semiarid and arid regions, but this does not necessarily imply the process of solonization.

Ravikovitch (1956) has recently discussed the suite of exchangeable cations in the brown-red sandy soils (i.e. hamra) of the Central Coastal Plain (Herzlia and Nes Ziona), and concluded on the basis of the relatively high percentage sodium plus magnesium saturation, that they are *solonetzic*. While purely chemical criteria have sometimes been used for the definition of solonetzic soils, most systems regard them as a corollary to the morphological properties. A significant characteristic is considered to be a columnar structured B-horizon, a distinct clay gradient due to migration of the dispersed clay resulting in poor permeability and associated highly alkaline *p*H, and a saline parent material. Infertility or even complete sterility is general. The red sandy soils and loamy sands under consideration do not exhibit any of these morphological features and the mere occurrence of some degree of sodium or magnesium saturation in the exchange complex thus seems hardly to justify their classification as solonetzic.

The sodium and magnesium saturation is derived, as pointed out by Ravikovitch, from a long-term continuous supply of salts in the precipitation, but it is unlikely that this will ever lead to a salinization of these highly permeable sandy soils. It is a common fact that far from being infertile these soils belong to some of the best citrus soils in the world, and it has never been shown that they require any management or fertilization practice significantly different from that of the normal hamra of the Coastal Plain.

Some other red sandy soils, which are devoid of lime and partially unsaturated, are called by Ravikovitch (1956) *degrading solonetzic* (Raanana, Kubeiba, Ein Vered), a process which is considered to be similar to solodization. In the extreme stage of degradation, according to Ravikovitch, the migration of colloids downwards results

in the formation of nazaz. A different and more likely origin of the nazaz horizon has already been mentioned previously (p. 100). The complete absence of lime in certain areas, and a higher sodium saturation in others, may be attributed to the expected variations in parent material in a dune landscape, and to the lateral movement of moisture in response to local topography. Leaching of carbonates and a continuous accession of soluble oceanogenic salts are normal and integral processes in the development of these soils.

Due to the variability in the parent material as a result of geomorphic processes, the textural profile does not show any consistent pattern. There are equally many profiles exhibiting a decreased content of clay with depth as there are profiles showing an increase. There seems thus to be hardly sufficient evidence for the process of degradation* and migration as alleged by Ravikovitch.

Soils from alluvium

The classification of soils developed from alluvial deposits has not received sufficient attention in general classification schemes. Great differences exist among soils generally called alluvial. The use of the term alluvial in itself is not very advantageous since it is meant to convey the mode of deposition of the material and not the subsequent soil forming process acting upon the material itself. In detailed soil surveys they are of course differentiated into a number of soil series according to local morphological characteristic, and this has been done in Palestine by Strahorn. Other workers have however not found it necessary to differentiate among them, except in the case of those affected by hydromorphic conditions. Yet there is little doubt that several varieties can be distinguished also among the well drained soils from alluvium. It would, for example, be useful to distinguish between deposits which are still aggrading and between those where aeolian or sheet erosion predominates over sedimentation.

Kubiena has extended the use of the term warp to include soils developed on river and erosion sediments, and he distinguishes several global types and subtypes according to morphological characteristics. Red to brown A(B)C soils derived from the erosion sediment of terra rossa are, for example, classified as *red warp soil* (vega), etc. Where the material in the (B) horizon is composed of material which is related to the parent soil the soil is called allochtonous, where it arises from weathering *in situ*

* Though degradation is often meant to imply increased leaching or simply a change to the worse, the writer prefers the pedologically more restricted definition signifying that properties acquired by a soil, and which would be retained under stable environmental conditions, disappear when these conditions are changed. This is generally caused by a change in climate, e.g. when due to higher precipitation forest begins to invade the chernozem area with the accompanying development of podzolization, of which the degraded chernozems are the first stage. Degraded soils therefore exhibit the characteristics of two successive evolutionary soil processes, and are typical examples of so-called polygenetic soils. In the final stage of degradation hardly any traces of the nature of the original soil are discernible.

It is unfortunate that degradation is also being used in the geophysical sense as the opposite of aggradation, with the meaning of deflation, truncation, erosion of the surface layer; *cf.* Rim (1954).

it is autochtonous. It seems that this approach may lead to a useful classification of recent soils from alluvium, even though differences may sometimes be difficult to discern. We could thus distinguish chocolate warp soil, rendzina warp soil (borovina), etc., with additional varieties depending on the balance between the eroding and depositional process, and on texture and structure development.

Soils of the desert

The soils of the desertic and arid regions of the Negev are too imperfectly known in order to point out any genetic relationship with other desert soils. In common with most desert soils they are shallow and skeletal, and usually without profile development. Local differences are mainly due to variations in parent rock and geomorphic history, and their constitution may often exhibit inherited features from previous climates. Observations in the Negev and Sinai deserts indicate that chemical processes have been important in sculpturing the landscape and that both physical and chemical weathering is active in rock disintegration. Practically all desertic soils in Israel, and in the Eastern Mediterranean as a whole, are grey to greyish brown in colour, as against many red desert soils found in America and Australia. The reason for this may be the high proportion of calcareous sedimentary formations in the Eastern Mediterranean, and the constant shifting and drifting of the fine calcareous material, which may have prevented the physico-chemical processes leading to the reddening of the deposits. In addition many of them are gypseous and saline.

A useful classification of the desertic soils should also be based on the study of their morphology, even though the various profile features which can be recognized may be largely due to their aggradational or erosional history, rather than to pedogenic origin. Typical desert soils of the Negev are the loamy light brown and grey soils of the highlands overlying certain limestones, and the *hammadas* (stone and gravel pavement) of the plateaus in the Southern Negev (Figure 5,) of which several subtypes have been recognized (Ravikovitch, Pines and Dan 1956). Several valleys are covered by loessial material transported from the uplands, and may be suitably called *wadi loess*. Many wadis are filled with coarse erosion deposits of variable origin. A large portion of these deposits are best classified as *regosols or lithosol.*

CONCLUDING OBSERVATIONS

The classification of soils in Israel, and previously Palestine, has largely been the work of a few individuals, each representing a different institution. This has led to understandable disagreements and differences in the nomenclature used. Although the major soil groups are easily recognized, their modal properties are as yet not well defined. In particular do we lack studies of genetic relationships among the various soil groups, and studies showing the effect of variation in one or two interdependent pedogenic factors on the resulting soil, i.e. studies of topographic and/or hydromorphic sequences.

The observations and suggestions put forward in the present paper are not the

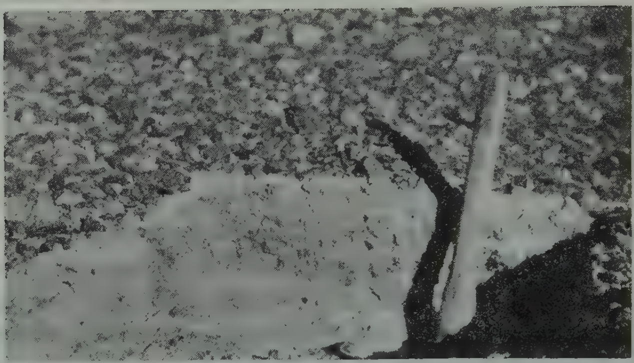

Figure 5
Hammada desert pavement of angular flint and limestone gravel and a silty, stone free subsoil, overlying soft marly and gypseous Neogene lacustrine deposits. The stratification is a combined result of pedogenic processes superimposed on variations in parent material. Note the complete absence of vegetation. (Northern Sinai)

outcome of a systematic survey of Israel soils, but of numerous observations made when opportunities arose to examine soils during trips in all parts of the country. It was originally intended to include detailed profile descriptions of all the major soil groups studied, but for reasons of space this had to be omitted. The reader is instead referred to published descriptions by Ravikovitch, Reifenberg, Rim, Strahorn, Zohary and others as quoted in the text. A number of photographs is however included to illustrate the main characteristics.

Considering the rather small area of the country, the number of distinct soil formations is rather large. As the previous discussion has shown, most of these soils can be morphologically and genetically correlated with similar soils in other countries and identified in world classification schemes. The writer is fully conscious of possible shortcomings and omissions in this comparison, but until a detailed survey of the soils of the country is carried out and its results published, the genetic significance of many soil characteristics cannot be fully assessed. It is regretted that no fuller comparison could have been made with other Mediterranean regions. This is partly because of the widely scattered and not always obtainable literature, and partly because the nomenclature used in the various countries is not sufficiently uniform or does not conform to present general usage.

The difficulties in finding representative counterparts for some of the soils demonstrates only too clearly what Robinson (1949, p. 460) called "the provisional character of the existing systems of classification". It is indeed necessary to accumulate a large body of quantitative data which will place the identity or dissimilarity of various soil groups beyond doubt. But, as already mentioned in the introductory chapter, it is for reasons of practicality that only certain groups of soils from the whole spectrum

of possible soil types are categorized and given names. Some of the difficulties are thus inherent in the system of soil classification itself. One cannot but conclude that the unification and standardization of soil classification systems is a highly desirable goal.

Some pedologic problems

The study of soil genesis in Israel is attended by numerous difficulties. Although climatically the country at best can be divided into three climatic zones: the subhumid Mediterranean, the semi arid and arid zones, the number of distinct soil groups is several times larger. The zonal concept fails therefore to be of significant help, as would of course be expected from the application of the functional analysis, which considers several independent soil forming factors to be of equal importance. It is only rarely that the climatic factor is sufficiently predominant to enable to relate the properties of the soil solely to the climatically controlled processes. The establishment of intrazonal and azonal orders evades the difficulty rather than solves it.

When "peculiar" soils which generally occur under certain climatic conditions are also found under a quite different climate, they are often thought to be relicts from previous periods, although they may have equally developed in response to a different combination of the normal soil forming factors. In arid and semiarid regions it is often difficult to decide to what extent the present day characteristics are a result of erosion and recent pedogenic activity, or how far they are residual properties from a previous, often more humid climate and a more active weathering. A number of pedologists, for example, still consider the terra rossa to be an essentially lateritic soil and relict from a previous humid tropical climate in an earlier geologic period (Joffe 1949, pp. 491–500), even though no terra rossa soils are found outside the area of the typically Mediterranean climate of today.

In solving problems of this sort it is first of all necessary to determine to what extent soil characteristics acquired during the pedogenic process are stable or "irreversible", and may be preserved in a second genetic cycle. The study of unmistakably polymorphic and polygenetic soils may serve as a guide in this respect and its seems that in particular the mineralogical and granulometric composition is helpful in distinguishing the various weathering and development stages (Rim 1955). Soil genesis will no doubt be better understood if we succeed in relating soil morphology and mineralogy more closely.

While in semiarid regions the nature of the parent material generally exerts the controlling influence on the behaviour of the soil and on its acquired characteristics, a complicating factor in determining the direction and mode of soil evolution is the widespread occurrence of aggradational, surface degradational and sortation processes which uninterruptedly take place and shift the soil material (Rim 1954). In Israel each parent rock has its own corresponding boundary of soil landscapes, yet within each geomorphic unit a number of genetically related soil types can develop. The coastal region is a significant example of an occurrence of this sort. It seems thus particularly

desirable that future soil geographic work follow hand in hand with detailed genetic studies of the soils mapped.

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A large number of articles on various aspects of soil classification was published after the completion of this paper and not all of these could be considered during the final corrections. Interest in soil classification has grown immensely during the last few years and it seems now that some sort of international agreement may become possible. While this paper was in press a symposium on "Soil Survey and Classification in Israel" was held in Rehovot (June 1959), at which a somewhat similar taxonomic comparison was presented by Miss H. Kojumdjiska. Many of the problems touched upon here were discussed, including a proposal for a revised classification of Israel soils by Y. Dan.

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THE STRUCTURE OF THE NORTHERN CARMEL

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ABSTRACT

The structural aspects of the detailed geological survey of the northern Carmel were dealt with. The evolution of the region is divided into three main periods: a. Pre-Paleocene movements, b. Main tectonic stage, and c. General uplift.

INTRODUCTION

The history of the geological research of the Carmel was reviewed in a recent paper by Picard and Kashai (1958) which also summarises the first results of a detailed survey carried out by them during the past few years. From 1956 to 1958, the author made geological investigations (on the scale 1 : 20,000) in the northern and western Carmel. The area surveyed (80 square kilometres) is bounded on the west by a sharp cliff line which is less pronounced in the north, and on the east is bounded by the big border fault. The mean height level is 250–300m above sea level.

STRATIGRAPHIC TERMS

The stratigraphic terms used by the author (see Figure 1) correspond generally to

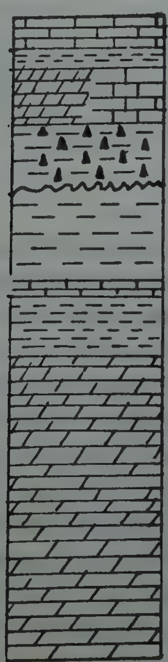

Figure 1
Schematic Columnar Section of the Northern Carmel 1:100,000

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those used by Picard and Kashai (1958) and Kashai (1958). The rock units are mainly dolomites, limestones and chalks.

1. *Yagur Dolomite.* (Lower Cenomanian?) + 380m. Massive to thin bedded, grey or brown dolomites with poorly preserved fauna. Numerous lenticular reefs appear, however, in some places.

2. *Main chalky Complex.* (Upper Cenomanian) 290m. This complex can be divided into the following formations:

a. *Isfiye Chalk* 60m. Unstratified chalky or marly strata with sporadic flint nodules. Well preserved fauna.

b. *Beit Oren Limestone* 30m. Coarse crystalline limestone ("meleke")with rudistides, passes to the NW into the "*Gryphea vesiculosa*" marly limestone.

c. *Khureibe Chalk* 80–110m. Chalky limestone with well preserved fauna.

d. *Shamir Chalk and Flint* 90–110m. Chalks with interbedded thin flint layers.

3. *Muhraqa Limestone and Dolomite.* (Upper Cenomanian to Lower Turonian) 70m. This formation appears in two facies: Dolomitic in the north and limestones in the south.

4. *Ein Haud Chalk.* (Upper Turonian) 25m. Chalk and marl with lenses of a yellow dense limestone.

5. *Ein Haud Lithographic Limestone.* (Upper Turonian) + 70m. Lithographic limestone ("hilu") with no megafossils.

THE STRUCTURAL EVOLUTION

The structural evolution of the northern Carmel can be divided into three main stages: a. Pre-Paleocene movements, b. Strong tectonic activity which occurred somewhere between the Upper Cretaceous and the Upper Tertiary, and c. General uplift (Upper Tertiary-Quarternary).

Pre-Paleocene movements

The more detailed study of the rock formations of Israel led to the assumption that tectonic movements connected with folding, faulting and uplift occurred as far back as the Cretaceous (Avnimelech 1936, Bentor and Vroman 1951–1957, 1954, 1956; Picard 1943, 1958). The stratigraphic column of the Carmel indicates also the possibility of early tectonic movements of a pre-Paleocene age. Their precise nature, however, is unknown as yet. We are dealing here with the evidence for tectonic activity which occurred during the post-Lower Cenomanian and pre-Paleocene period.

a. *Unconformities.* A discordance between the Yagur Dolomite (Lower Cenomanian) and the Isfiye Chalk (Upper Cenomanian) was found in a number of places. This discordance, even if small, is proved by the following:

1. A difference in the strikes and dips of the above-mentioned formations was observed. It should be noted, however, that exact measurements could be taken only in few localities (Haifa Metro tunnel, Abu Qalb quarry etc.) due to the imperfect

stratification in the Isfiye Chalk. In each case the difference between the strike lines was in the range of 10–30°.

2. The Yagur Dolomite was found to be occasionally overlain by a layer of red-brown clay or by a less conspicuous zone of weathering (Haifa Metro tunnel, 80cm. thick; Hapoel street, Haifa, about 2m. thick).

3. In the western part of the Wadi Shelale, the contact between the Yagur Dolomite and the Isfiye Chalk is not regular but is of an undulating nature. In some places little pockets of chalk were found in the dolomites; in other localities, large dolomitic boulders were found above this contact.

b. *Slight undulations in the Cenomanian and Turonian formations.* These undulations are indicated by sudden reversals of dips in areas where no faulting is in evidence. (Ahuza, N. Tira).

c. *Facies changes.* Marked lateral facies changes occurring in the northern Carmel were found to be characteristic of the Cenomanian and Turonian formations. A few examples of these changes are:

1. The Muhraqa formation appears in two main facies: a dolomitic in the north, and reefy limestones in the south.

2. The Ein Haud marl and lithographic limestone, with the frequent occurrence of limey lenses and limey or quartzolithic reefs (*Hippurites* sp., *Acteonella* cf. *obtusa* Zekkel, *Nerinea* sp:) appear to be equivalent to the Daliya Chalk (Picard and Kashai 1958) found in the east and south. The detailed correlation of the rock units of the northern Carmel with those of the southern Carmel, awaits, however, the publication of the results of the researches carried out by Kashai.

d. *Paleocene outcrop on the Kinyan Hill.* The only outcrop of Paleocene strata found to date in the Carmel is that of the Kinyan hill in Ahuza (1488/2438)*. This chalk was examined by Z. Reiss of the Geological Survey, and an Upper Landenian age was attributed to these strata due to the presence of:

Alabamina wilcoxensis Toulmin
Nuttalides trumpy Nuttal
Eponides umbonata Reuss
Truncorotalia simulatilis Schwager
Truncorotalia wilcoxensis Cushman and Penton
Truncorotalia velascoensis Cushman
Pseudovalvulineria "*danica*".

The chalk (slightly bituminous) unconformably overlies the Muhraqa Dolomite along a fault zone (see Figure 2). The fault is therefore of a pre-Paleocene age. It may have led to the origin of a depression, later filled with the Paleocene sediments which were preserved in this locality, whereas the other Paleocene strata in the neighbourhood were most likely removed by a later erosion.

* It may well be that the strongly weathered chalks which appear on the western side of the Feloch faults are also of Paleocene age. No fauna was found however in these chalks.

The presence of this Cenomanian / Paleocene unconformity, suggests a pre-Paleocene vertical movement.

e. *Volcanics*. The frequent appearance of volcanics in the Cenomanian and Turonian formations of the Carmel, as reported by the various investigators, seems to indicate again, unstable conditions in the crust during the Upper Cretaceous of

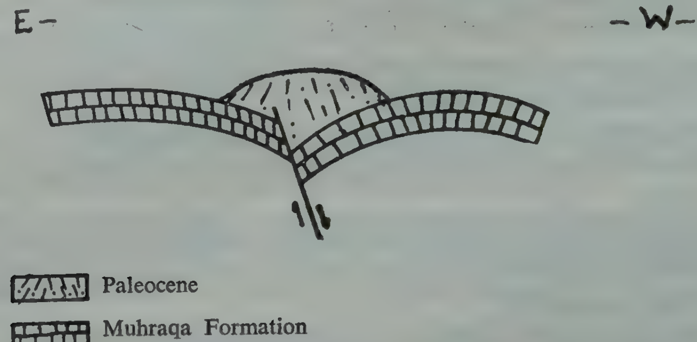


Figure 2
The Paleocene of the Kinyan Hill

this region. E. Sass (1958) recognises several volcanic centres in the different regions of the Carmel.

Main tectonic activity

According to Picard and Kashai (1958) the Carmel is a folded upwarp, composed of a number of anticlines which were later faulted into major and minor blocks and which have undergone a later general uplift.

Fault elements

Tel Hanan — Cape Carmel fault. This fault is a part of the eastern border fault line of the Carmel (Yokneam–Yagur–Haifa). It starts near Yagur (1550/2410) and follows the border of the Carmel Mountains to Cape Carmel, and here enters the sea. This fault line, however, may be composed of a number of short faults with equal throw and hade.

Yagur – Makali fault. This fault which branches off from the eastern border fault near the point 1560/2400, and trends N 60° W, is an antithetic rotational fault with a pivot near the point 1524/2412. Reversal of the direction of throw beyond this point suggests an asymmetric hinge fault, but an additional fault, oblique to the Yagur–Makali line, suppresses the evidence for it (Figure 3 II).

Nesher Eocene graben. Occurrence of small triangular area of Lower Eocene near Nesher (1555/2405), was first reported by Picard (1929) and mapped as a graben downfaulted on the SE and on the NW against the Cenomanian. The Lower Eocene is overlain discordantly by Pliocene strata, which were found to be of a clearly littoral character. Thus, it seems that in Pliocene times, this area was depressed rela-

tively to the Carmel Mountains. This depression, which provided an entry for the Pliocene sea, is believed by the author to result from the Yagur-Makali downfaulting (Figure 3 I, II, III).

The faults on the sides of this triangular area are (as shown on the various geological maps) of a small linear extent, although their throw is large. When these

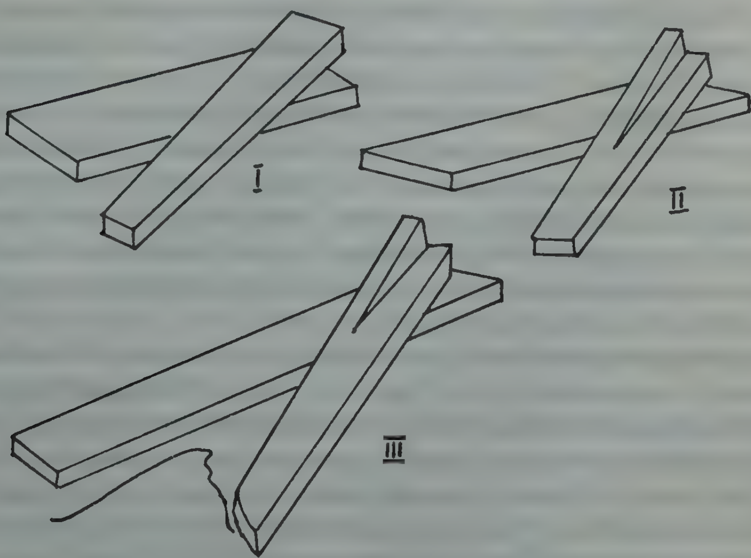


Figure 3
Yagur Makali Fault
I. Hinge Faulting
II. Secondary Fault
III. Transgression of the Younger Sea

faults were recently examined in the field, no clear evidence of faulting was found on the NW side of the triangle. On the ES side the fault zone is clearly established by a wide breccia zone. There is, however, no evidence that this fault is responsible for the present position of the Lower Eocene strata. On the contrary, in some places the Eocene strata were found to overly the breccia. No Eocene fragments were found as yet in the breccia itself. The steep dips near the fault line (which may have been caused by the early uplifting of the Carmel Mountains) diminish gradually (and not as abruptly as one would expect in a fault-dragged zone), and in the NE part of the area, the dip is 15–30°. There is then a possibility that the Eocene (or even older strata) overlies discordantly the Cenomanian. This assumption, if true, would mean that an elevated relief existed already in the Lower Eocene which did not permit its deposition on the Carmel Mountains (and indeed, no Eocene outcrops were found as yet on the Carmel), except for the depression caused by the Yagur-Makali downfaulting.

On the other hand the open sea character and the absence of the littoral phenomena in the Eocene strata contradict this assumption.

Nesher horst. As the dolomites of the Nesher hill were found to belong to the Muhraqa formation and not to the Yagur Dolomite (Lower Cenomanian) as thought previously, no such structure seems to exist.

Northern border fault. This fault line, found on the various geological maps along the arc Shikmona – Kiryat Eliahu (1465/2475 to 1485/2475), does not seem to exist. a. Along the Shikmona-Neuhardhof coast, dolomites are exposed. These dolomites belong to the Muhraqa formation and can be traced up to the mountains (Stella Maris, Ramat Shaul). b. In Bat Galim and Shikmona, the Shamir Chalk and Flint appear and are continuous with the same strata of the mountains. c. The strikes and dips at the foot of the mountains (in the above mentioned areas) are identical with those observed on the formations on Mt. Carmel. d. The steep slope of the Upper Hadar Hacarmel (Haifa) and of Stella Maris resulted from the Haifa fault which trends from the point 1500/2465 to Cape Carmel. This fault produced the wide talus slope zone and breccia of the northern slope of the Upper Hadar and is responsible as well, for the morphologic step of the Lower Hadar.

Western border fault. Mt. Carmel was previously believed to be a horst bordered on all sides by large normal faults. Picard and Kashai (1958) and Picard (1958), however, indicate only one border fault (on the east), which the present study confirms. The western cliffs of the Carmel, thought previously to indicate a fault line, are probably the result of abrasion. However, as the subsurface of the Carmel Coastal Plain is but a continuation of the Carmel, many faults of N/S and NW/SE directions cross the area between the coast and the western scarps of the Carmel (some of them represent the continuations of the transversal faults of the Carmel).

Wadi Maghara fault. The Maghara fault which has a throw of 500–600m. near Mazar (1470/2320) diminishes rapidly to the south. The age of the Maghara dolomites was for a long time a matter of controversy between the various investigators. Most of them, including the author, consider it now to Lower Cenomanian. The reasons of the author are as follows: a. The Maghara dolomites are at least 250m. thick, while the Muhraqa formation (Upper Cenomanian–Lower Turonian) to which the formation the dolomites were thought to belong, attains a thickness of only 0–80m. b. In the normally downfaulted block of the Maghara fault, Upper Cenomanian (Khureibe Chalk) fossils were found (*Mantelliceras* sp. *Gryphea vesiculosa* Sow. *Orbitolina concava* Lmk.). c. The Maghara dolomite–limestone reef contains rudistides of the lower part of the Cenomanian (*Eoradiolites lyratus* Conrad, *Sphaerulites* sp.).* d. On the southern side of the Wadi Maghara, the dolomites were found to be overlain by 70m. chalks followed by a *Gryphea vesiculosa* Sow. bank (corresponding to the Isfiye Chalk followed by the "Gryphea" bank, which overlies the Yagur Dolomite of Lower Cenomanian age).

Fold elements

Neve Shaanan block. The Neve Shaanan block which extends from Tel Hanan

* Parnas, A. and Kashai, E., *Private Communication*

(1545/2415) to Cape Carmel, is NW/SE aligned and is bounded on the east by the Tel Hanan–Cape Carmel fault. Lower Cenomanian dolomites are exposed in the core of this structure. This block can be divided into three main parts which differ in their dip directions:

a. SE part (beginning at 1517/2427) dips 15–40° to the SE.

b. NW part (beginning at 1505/2455) dips 10–25° to the NW.

c. Central part, located between the above two, dips 7–12° to the south and southwest.

This block was considered to be an asymmetric to the east anticline, faulted near the axis and parallel to it.

No such axis (NW/SE directed) was found, however, and no dips to the east and northeast have been observed (The only dips in directions mentioned were found in the fault zone and are in our opinion fault drag phenomena).

The change in dips from the central part to the sides is very gradual and gives a clear picture of a plunge.

It should also be noted that the rate of folding is small while the faulting is large and strongly pronounced.

It seems that the Neve Shaanan block is to be considered rather as a half–dome which resulted from the same stresses which produced the faulting. This opinion is illustrated in Figure 4 and in the structural contour map.

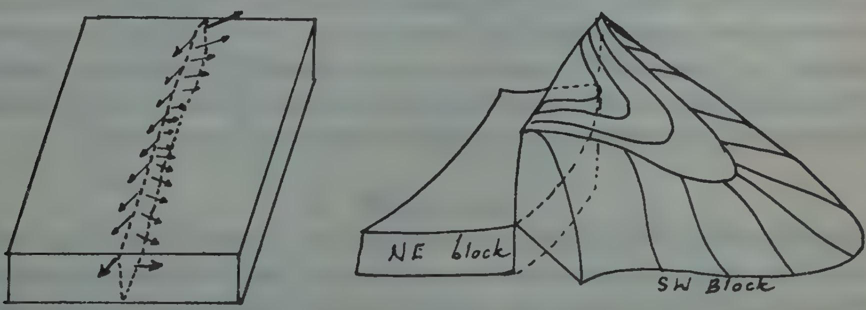


Figure 4
Formation of a half-dome along normal fault

For the mechanism of the formation of this structure, we follow in general the views held by de Sitter (1956), Nevin (1942) and Goguel (1954).

1. The growth of tension in the crust is followed by a beginning of faulting. Simultaneously, the folding was initiated, due, partly to the drag on the fault and mainly to the horizontal stresses produced by the regional field of stress and by the normal faulting itself. The maximum stresses were concentrated at the ends of the fault (which explains the fact that the plunge on both the sides is larger then the dip of the central part) (Anderson 1951).

2. Continued downward movement of the NE block, and a continuation of the

stresses acting on the SW block, resulted in a half dome parallel to the main NW/SE directed border fault line.

Accordingly, no buried half of an anticline, facing the Neve Shaanan block, would be found under the younger sedimentary cover of the Kishon Plain. The expected (Figure 4) basin-like structure of this area is confirmed by the geophysical data.

It may be that similar phenomena of half-doming along a normal fault appear in other places on the upfaulted sides of the Esdraelon Valley (Emeq Yizreel).

Isfiye block. This structure was mapped by Kashai and only the NW extension of it was surveyed in the course of the present study. It may well be that the Isfiye block originated simultaneously with the Neve Shaanan block, along the eastern border fault. The separation of the blocks is attributed to the Yagur-Makali fault (whether considered a transversal fault or a crescentic continuation of the border fault), simultaneous with the initiation of folding.

Shelale block. The fold axis of this structure trends NW/SE and passes between the points 1502/2372 and 1501/23695. This structure is an elongated dome asymmetric to the east, and dissected on its western flank by the two parallel Felach faults (which diminish abruptly and die towards the SE) and on the eastern flank by the smaller Beit Oren fault.

Damun-Tira trough. This comparatively narrow structure is but a part of the zone located between the two main fold lines of the Carmel (Structural sketch map). The Damun-Tira through consists of three parts: a. Damun "bowl" asymmetric to the east, b. Tira region, the precise structure of which is concealed by faulting. It is also possible that a small secondary fold is present near the sprig Umm-Sharqive (1498/2404); and c. Tira-Haifa zone, hidden beneath the Coastal Plain.

General Uplift

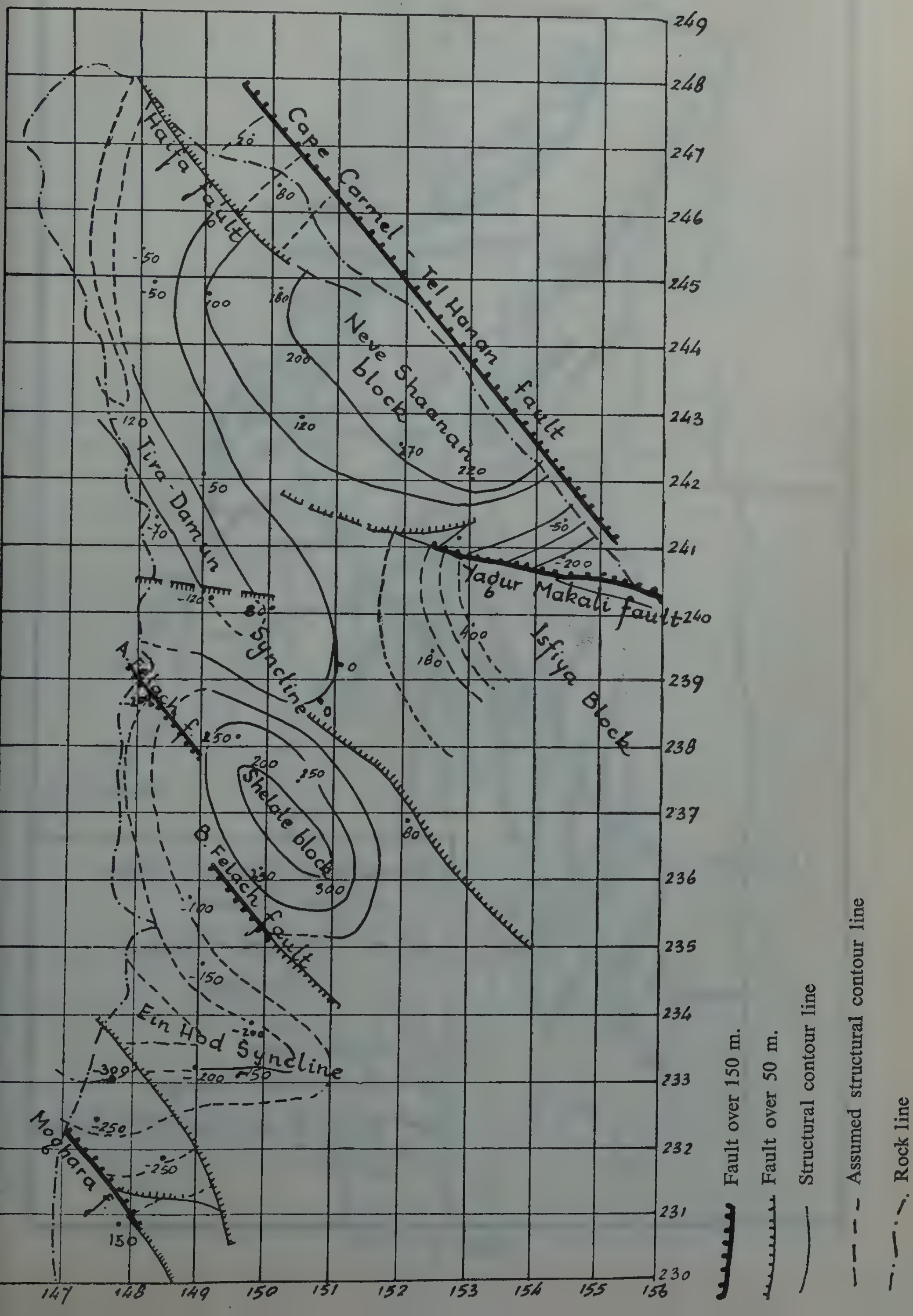
Picard and Kashai (1958) reported the occurrence of Miocene strata at the height of 400m. The various investigators observed relics of marine terraces of supposed Pleistocene age (mainly calcareous sand). A marine (Pleistocene?) conglomerate was found by the author at a height of 90m (Arlosoroff street, Haifa). This conglomerate was reported also by A. Shilo (1958) from the Haifa Metro tunnel.

These young strata at various heights on the Carmel, indicate clearly an Upper Tertiary–Quarternary uplift.

SUMMARY

The presence of an unconformity between the Lower Cemomanian and the Upper Cenomanian, the unconformity Upper Cenomanian/Paleocene, the undulations in the Cenomanian and Turonian formations, the frequent appearance of volcanics and the occurrence of the facies changes, indicate tectonic activity during the Lower Cenomanian–Paleocene period. The time of the occurrence of the main tectonic events is as yet not known precisely and is considered to have taken place somewhere

Figure 5
Structural Map of the Northern Carmel 1:100,000 by Y. Karcz
Key horizon—Top Yagur Dolomite



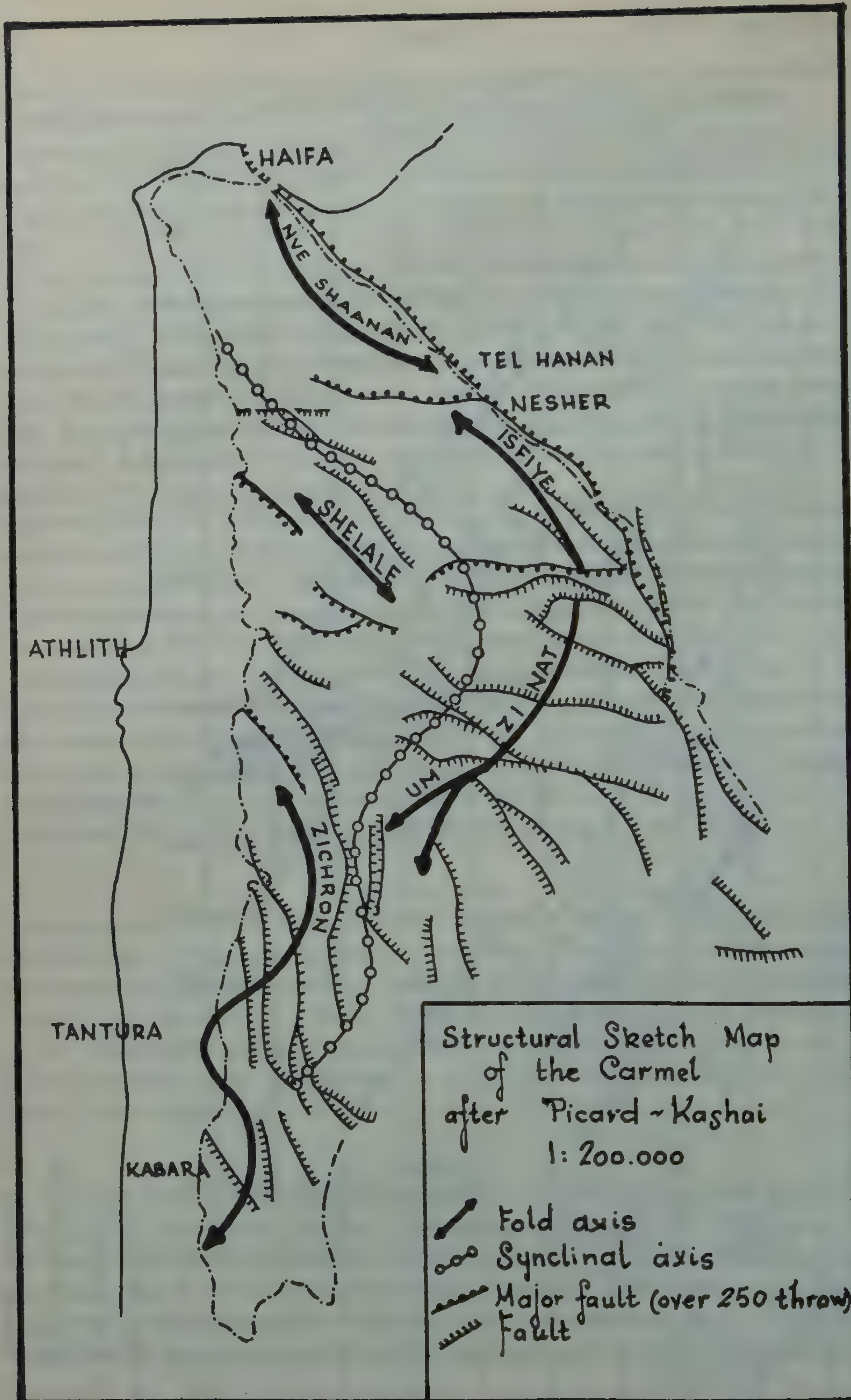
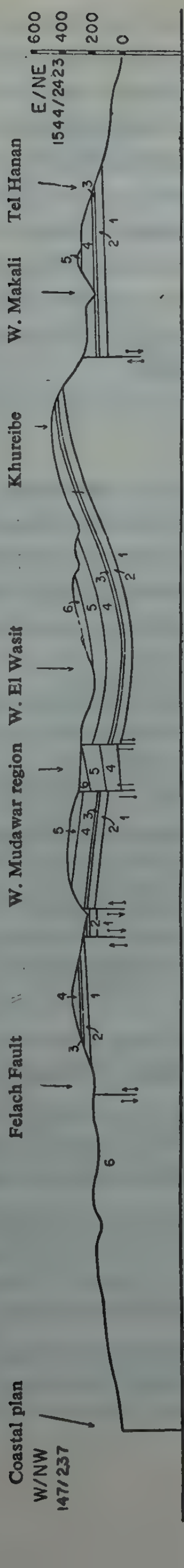

HAIFA
NVE SHAANAN
TEL HANAN
NESHER
ISFIYE
SHELALE
ATHLITH
NAT
ZI
UM
ZICHRON
TANTURA
KABARA
Structural Sketch Map
of the Carmel
after Picard - Kashai
1: 200.000
Fold axis
Synclinal axis
Major fault (over 250 throw)
Fault

Figure 6

Cross-section through the Northwestern Carmel (Scale 1:20,000)



1. Yagur Dolomite
2. Isfiye Chalk
3. Beit Oren Limestone
4. Khureibe Chalk
5. Shamir Chalk Flint
6. Muhraqa Limestone

between the Upper Cretaceous and the Upper Tertiary. Normal faulting was produced along the line Yokneam–Haifa, which is directed NW/SE in the northern part of it and N/S in the southern part. Simultaneously, compression, which resulted from the regional field of stress and which was strengthened by the normal faulting, gave rise to two subparallel arcs aligned along the border fault (Sketch map). The major one consists of the Neve Shaanan, Isfiye and Umm az Zinat and the minor one, in the west, consists of smaller structures of Shelale, Maghara and Zikhron. Between these two fold lines a narrow synclinal zone is found.

The subdivision into seperate blocks occurred after the initiation of folding. The transversal faulting diminished gradually to the west (like folding) and gave place to the NW/SE and N/S directed faults.

Finally during the Upper Tertiary–Quarternary period a general uplift of the region occurred.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to Prof. Picard for his guidance in the present study, to P. Grader for his criticism and help in preparing the English text and to the members of tne staff of the Department of Geology, The Hebrew University of Jerusalem, for criticism and advice in the preparation of the manuscript.

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THE OCCURRENCE OF *LOPHORANINA* CRUSTACEA: DECAPODA: RANINIDAE: IN THE MIDDLE EOCENE OF ISRAEL

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ABSTRACT

A specimen of *Lophoranina marestiana* (Koenig), found in the Middle Eocene of the Lower Galilee (Israel), serves as additional evidence that this group of Decapoda lived in the northern (European) as well as in the southern (Venezuelan–North African) neritic zones of the Tethys.

Thanks to Mr. Eviathar Nevo, instructor at the Teachers' College of Oranim, near Haifa, I received for examination a rather well-preserved fossil fragment of a crustacean from the Middle Eocene of Mt. Arbel (near Tiberias), in the Lower Galilee of Israel. The fossil was found by Mr. Ehud Arbel of the nearby settlement of Ginossar.

The fossil is preserved as both a positive and negative print of an almost completely preserved crustacean carapace of which only the anterior and posterior fringes are missing. The rock is a yellowish to brown-pinkish marmorized limestone, the slide of which shows many Globigerinas and other micro-foraminifera together with several fragments of *Discocyclina* and *Operculina*. It is a typical Middle Eocene rock, lithologically very similar to the local Turonian marble. As the latter, the Eocene rock is characterized by stylolithic structures, but these occur here in a much lesser degree than in the Turonian rock.

The carapace fragment is approximately 50 mm long, and up to 50 mm in breadth; its original length can be estimated at about 70 mm, whereas its breadth could not have been much more than 50 mm. Attempts to disclose details of the anterior and posterior fringes failed on account of the hard and splintery nature of the rock; further probing would have been injurious to the specimen. Moreover, as the general shape and ornamentation of the carapace were sufficiently definite, any further work on it seemed superfluous. In shape, this carapace is broadly oval, with slightly rounded sides which gradually narrow towards the caudal border; it possesses a low relief, being elevated in its central portion by no more than 10 mm. The surface of the carapace is ornamented transversely with numerous low, roughly parallel ridges, which descend slightly towards the centre; these ridges are densely pectinated with numerous denticles of uniform size and shape. Most of the ridges traverse the carapace from one side to the other, but there are a few which run from the border and die out before reaching the centre. In the median region of the carapace, almost at its

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centre, lie two short furrows, slightly and symmetrically inclined towards the medial line. On the left side of the carapace a large fragment of the first pereiopode is visible; as this is unfortunately splintered longitudinally, the details of its external shape are lost.

These characteristic features leave no doubt that the carapace is to be classified as the raninid genus *Lophoranina*(Fabiani 1910), and that it belongs specifically to the relatively abundant *Lophoranina marestiana* (Koenig 1825).

There are several discrepancies as to the systematic classification of the *Ranina* group. In Roger's (1953) opinion the superfamily of *Gymnopleura* Bourne 1922 replaces the "*Raninidae* Dana"; he does not divide this superfamily into families, although he lists quite a large number of genera. The genus *Ranina* is split into the

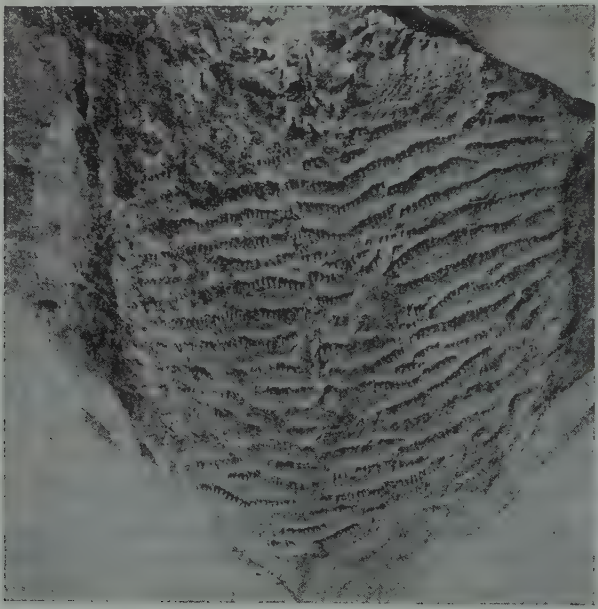

Figure 1
A specimen of *Lophoranina marestiana* (Koenig), found in the Middle Eocene of the Lower Galilee (Israel)

subgenera *Ranina* s.s. (=*Hela* Muenster 1840), *Laeviranina* Loerenthey 1929 and *Lophoranina* Fabiani 1910 (= *Palaeonotopus* Brocchi 1877 pars). Thus, Roger does not follow Beurlen (1930), who divides the subtribus *Gymnopleura* (= *Raninoidea* auct.) of the tribus *Oxystomata* into two families: *Raninellidae* Beurlen and *Raninidae* Dana. This last family, according to Beurlen, includes the following genera: Paleogene: *Laeviranina*, *Lophoranina*, *Notoporanina*, *Notopella*, *Hela*, *Ranidina*; Neogene: *Ranina*, *Notopoides*, *Lyreidus*, *Tribolocephalus*; Recent: not listed, but the remark is made: "few living genera known".

It seems that at least in regard to *Lophoranina* the generic status, as admitted by Beurlen, is well founded on morphological characters — especially with respect to the pectinated crossridges of the carapace — and also on account of its stratigraphical position. Its generotype is *Lophoranina marestiana* (Koenig) which is known to occur in the Middle and Upper Eocene of Italy, Bavaria, Austria and Hungary; from the Middle Eocene of Egypt ("Mokattam-stage") the authors (Bittner 1875, Glaessner 1929, Lorenthey 1908) record *Lophoranina bittneri*, *L. cf. marestiana*, *L. reussi*, *L.* sp. (? *laevifrons*).

The specimen of *L. marestiana* from Mt. Arbel, near Tiberias, corresponds exactly with the specimens from northern Italy which were collected or purchased and discussed by P. Oppenheim (1896) and which are now in the collections of the Hebrew University Geological Department (Nos. 19470–19474, from the localities: Cave Scole in Vale d'Avesa, Brusaferri near Bolca, Chiampo, Chiuppio and Barbarano). The presence of this species in Palestine is a useful addition to the list of forms found in Egypt and it appears likely, therefore, that designations such as "cf. *marestiana*", "sp. (? *laevifrons*)" — or even "*bittneri*" — refer in reality to *L. marestiana*. The slight deviation in the sculpture (the cross-ridges of the carapace) do not seem to be of critical impotance, especially as in most cases the examined material was more or less fragmentary.

Noting the presence in Egypt of *L. reussi* (Woodward) and *L. bittneri* (Loerenthey), Loerenthey (1904/1907) has already pointed out that "the Raninas of the older type were, up till now, unknown in Africa. It is, therefore, especially interesting to find, in the Mokattam outcrops, two *Ranina*-species ornamented with the denticulated ridges, of which one, *R. reussi* Woodward, could be regarded as the most common and most characteristic form". In accordance with this statement it should be borne in mind that already in 1866, H. Woodward published a note announcing the presence of such an old type of *Ranina* ornamented with "transverse pectinated ridges" (= "*Ranina porifera* Woodward") in the Tertiary sediments of Trinidad. Thus, in the south of the Tethial ocean,the *Lophoranina* species were present in the Venezuelan as well as in the Egyptian-Syrian regions. It is highly probable that they were present in the connecting regions also, but their remnants have, up to now, been overlooked. The northern areas, in which *Lophoranina* occurs, are relatively continuous, comprising northern Italy, Austria, Hungary and Bavaria; its presence should be expected also in the Caucasus and other countries of Central Asia. Accordingly, the L*ophoranina* species made its way along neritic zones of the northern and southern Tethys.

The relatively scarce documentation of *Lophoranina* in the quoted regions finds its explanation in the unfavourable nature of the crustacean exoskeleton for fossilization, and hence its usually fragmentary preservation with more or less advanced obliteration of the external features; these render exact determination difficult or uncertain.

The present demarcation of *Ranina* life-zones in the Indo-Pacific region, from Japan to the Mauritius Islands, is in agreement with those of numerous living organisms which today are but the remnants of former highly flourishing and important animal

groups (e.g. *Nautilus*). Moreover, it seems that as in many other cases (e.g. *Actaeon*), the organisms of these groups live today in generally deeper zones than in former times. The usual association of *Lophoranina* with big foraminifera, such as *Nummulites*, *Operculina*, *Discocyclina* and such benthonic genera as *Tubulostium*, shows that *Lophoranina* belonged to a benthos of no great depth, whereas the *Ranina* of today are reported to be restricted to rather deeper neritic zones.

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SOME PHYSICAL PROPERTIES OF LOESS SOILS IN ISRAEL

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ABSTRACT

The loess of the South of Israel was studied from the point of view of its technical properties and an attempt was made to investigate its origin and manner of formation. Granulometric and mineralogical analyses carried out on several samples of loess and other soils from farther north showed the major part of the loess and other soils to be a mixture of aeolian loess and alluvial clay. This distinction between aeolian and alluvial loess is of great practical importance.

INTRODUCTION

In connection with a search for dam sites in the southern part of Israel, the manner of formation, the composition, and engineering properties of loessial soils were studied and compared with loessial soils abroad.

In previous studies a mixed aeolian and aquatic origin has been proposed for the Israel loess, and this view was expressed by L. Picard in 1943: "... loess is a basin sediment deposited and often redeposited by wind and partly by river floods from the Middle Pliocene to the present". A similar view was held by the late Prof. A. Reifenberg (1947) but seems to be opposed by Prof. Ravikovich (1952). Based on analyses of heavy minerals, Vroman concluded that the loess is formed mainly by dust brought by the southwestern winds coming from Egypt and that this dust can be found as far north as Jerusalem or even Galilee.

The purpose of this study was to add some information on the above subject and to get a better comprehension of the engineering properties of the loess. Mechanical analyses were made on a number of soils, and the mineralogical composition was determined for each fraction in representative samples.

DESCRIPTION OF THE SAMPLES

Typical samples were taken at depths reaching 20–25 metres within the loess area and the alluvial plain north of it. From hundreds of samples tested only six are given here, taken on an approximate south–north line from the Beersheba loess to the Nahal Grar clay (see map — Figure 1).

A typical profile in the loess area, as shown by deep borings or test pits would be as follows:

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Thickness (metres)	Geological description	Engineering classification (U.S. B.R.) (5)
Up to 6	Loess, loose texture yellowish, *wind-borne*	Silt of very low plasticity (ML)*
Up to 15	Loess, clayey, especially towards the base, often stratified, enclosing gravel lenses, *reworked* by floods	Lean clay, silty, of medium plasticity, (CL); the lenses being (GW-GP)
Up to 12	Gravel, sandy and clayey	Gravel, with sand-silt-clay binder more or less well graded (GW–GP)
	Bedrock, mostly Eocene chalk, sometimes Neogene soft series	

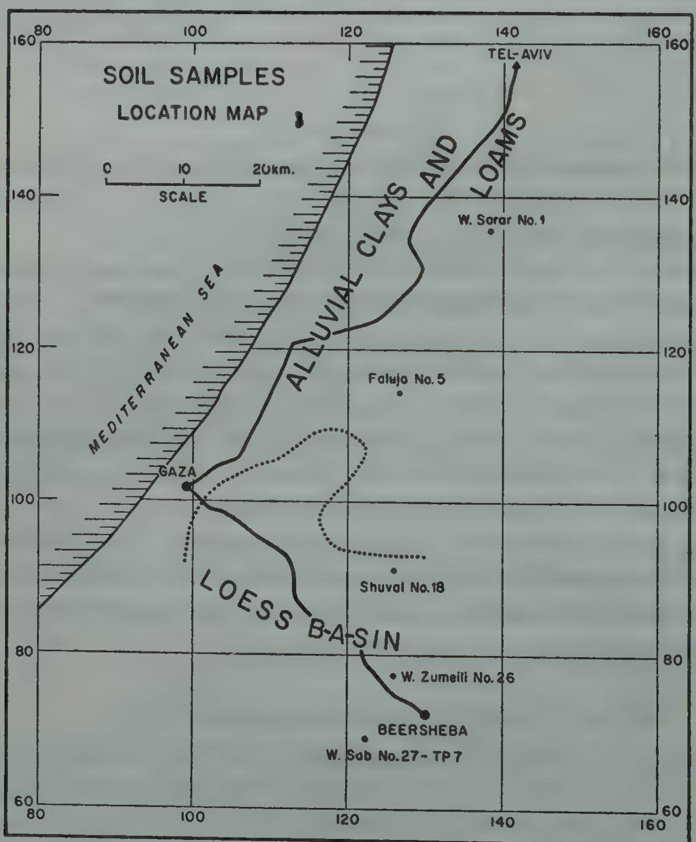


Figure 1

* ML—silt of low compressibility; CL—clay of low compressibility; GW—gravel, well graded; GP—gravel, poorly graded.

The loess formation gradually disappears towards the north and gives place to an alluvial clay referred to by engineers as CL or CH (clay of low or high compressibility).

The location of the samples is shown in the attached map (Figure 1) and their description summarized in Table I.

TABLE I

Origin of sample	Denomination		Percentage	
	Geological	Engineering	Loess	Clay
Nahal Beersheba (Wadi Sab) No. 27	Loess, aeolian	ML—CL	80	20
Nahal Beersheba (Wadi Sab) TP No. 7	Loess, reworked	CL	55	45
Nahal Patish (Wadi Zumeili) No. 26	Loess, aeolian	ML—CL	100	0
Shoval (Shuval) No. 18	Loess, reworked	CL	45	55
Plugot (Faluja) No. 5	Clay, alluvial	CL—CH	60	40
Nahal Shorek (Wadi Sarar) No. 1	Clay, alluvial	Cl—CH	55	45

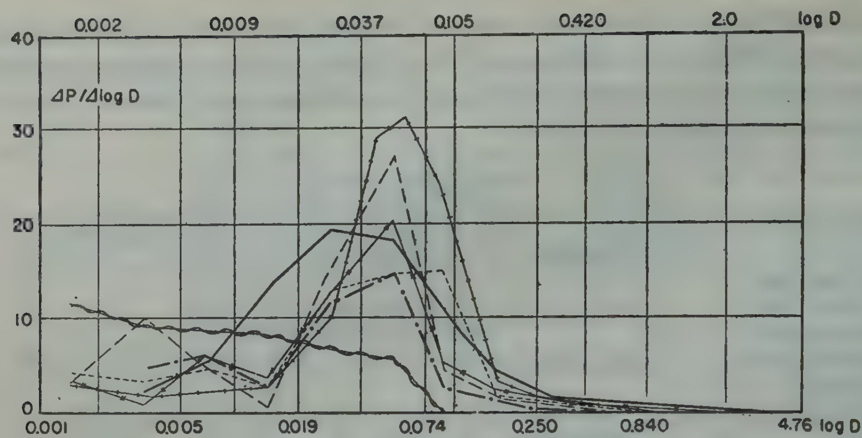
DESCRIPTION OF TESTS

Mechanical analyses have been made according to the Bureau of Reclamation standard methods (sieving and hydrometer) (1951), using sodium silicate as a dispersant. Above 0.07 mm seven fractions were obtained by sieving, and below this size five fractions were taken with the pripet. In fractions above 0.002 mm mineralogical analyses were made by counting the grains. For smaller sizes X-rays and thermic methods were used.

RESULTS OF MECHANICAL ANALYSES

In the "differential" grain-size diagram which has been used (Figure 2), the abscissa is the logarithm of the diameter D and the ordinate the expression $\Delta P/\Delta \log D$ where P is the weight of material finer than D. This kind of diagram has been described and successfully used by Bagnold (1941) for the determination of various sands in Africa. Its advantage is that it can be separated into primary diagrams and shows whether the sample consists of one or more elements. The surface between the abscissa axis and each of the primary diagrams is proportional to the weight of the corresponding elements.

The Wadi Zumeili diagram in Figure 2 is typical for wind-borne loess, its form approaching that of the theoretical Gauss diagram which here is the expression of the random action of the wind carrying grains between 0.037 and 0.074 mm in diameter. The other diagrams show that the corresponding samples are mixtures of two elements: a wind-borne loess like in Wadi Zumeili and an alluvial clay (Table I). It is thus seen that a large part of the so-called loess is of alluvial origin, while genuine wind-



Faluja No. 5 12670/11450 alluvial clay 0.2m deep
Wadi Sab No. 27 12100/6950 aeolian loess 0.2m deep
Wadi Zumeili No. 26 12300/0790 aeolian loess 0.3m deep
Wadi Sarar No. 1 13858/13520 alluvial clay 0.2m deep
Wadi Sab TP 7 12100/6950 reworked loess 2.0m deep
Shuval No. 18 12600/09124 reworked loess 0.2m deep
Emek Beth Netofa fat clay (for comparison)

Figure 2

borne loess has penetrated far north of the loess basin and has mixed with the alluvia clays and loams. The diagram for Beit Netofa Valley fat clay has been given for comparison.

RESULTS OF MINERALOGICAL ANALYSES

We see (Table II) that the fraction 0.037–0.047 mm is the larger one in all the samples especially in the aeolian loess and has a rather constant composition, with quartz predominating together with heavy minerals originating from the decomposition of magmatic rocks.

This again shows that the loess is an important component of the investigated soils.

ACKNOWLEDGEMENTS

The mechanical analyses have been made in the Soil Mechanics Laboratory of Water Planning for Israel Ltd. Dr J. Vroman of the Technion–Israel Institute of Technology, Haifa, has made the determination of the soil minerals other than the clay ones. The latter have been determined in the Delft (Holland) Soil Mechanics Laboratory. A number of samples have been analysed in the Denver (U.S.A.) Bureau of Reclamation Laboratories.

TABLE II

Mineral composition of soils in south Israel
(after Dr. Vroman)

Particle size (mm)		Wadi Sab No. 27 Aeolian loess		Wadi Sab T.P. 7 Alluvial loess		Wadi Sarar No. 1 Alluvial clay	
		I	II	I	II	I	II
4.76–2.00	L				20		100
	Sh			0.3		0.1	
2.00–0.84	L		100		15		97
	Sh	1.5		0.2	85	0.2	2
	Q						1
0.84–0.42	L		100		37		91
	Sh	1.0		0.5	63	0.3	7
							2
0.42–0.25	L		23		50		87
	Sh	0.3	68	0.2	40	0.8	1
	Q		9		10		12
0.25–0.105	L		8		13		75
	Sh		7		2		1
	Q	5.8	84	3.7	83	3.1	24
	O		1		1		
	T				1		
0.105–0.074	L		7		2		9
	Sh				2		1
	Q		90		95		85
	H	14.0	3	9.3	1	2.8	
	O						3
	Z						2
0.074–0.037	L		1				3
	Q		89		84		94
	C		1		2		
	O		3		6		1
	E	40.9		19.9	2	26.0	1
	H		3		2		1
	Z				2		
	R		3		2		
0.037–0.019	Q		94		82		
	C		4		14		
	Q				1		
	H	13.5	1	14.3	1		
	R				2		
	Bi		1				
0.019–0.009	Q		60		49		
	C		33		24		
	O				6		
	Z				10		
	Bi	2.7		4.3	3		
	R				3		
	Ch		6		5		
	H		1				
0.009–0.005	Q				42		
	C				40		
	O				2		
	Z			5.5	2		
	Bi				1		
	Ch				13		

L = Limestone
Sh = Shell
Q = quartz
O = opaque
T = tourmaline
H = hornblende
C = calcite
E = epidote
Z = zircon
R = rutile
Ch = chlorite
Bi = biotite

I = % of fraction (weight of sample)
II = % of minerals in fraction (weight)

In Table III the approximate composition of the fraction below 2 microns is given.

TABLE III

Origin of Sample	Geological nomenclature	Quartz %	Kaolinite %	Illite %	Mont-morillonite %
Nahal Beersheba (Wadi Sab) No. 27	Loess, aeolian	10	15	50	25
Shoval (Shuval) No. 18	Loess, reworked	5	10	30	55
Plugot (Faluja) No. 5	Clay, alluvial	5	10	5	80
Nahal Shorek Wiadi Sarar) No. 1	Clay, alluvial	10	15	10	65
Balt Netofa Veley)	Clay, alluvial	10	10	0	80

Here, we see that while illite is the most important mineral in aeolian loess, montmorillonite is the predominating clay mineral in alluvial formations.

A mineralogical analysis was made in Denver (1951) on a sample of aeolian loess, somewhat clayey, from Wadi Zumeili. It shows:

Quartz	45%	Biotite	3%
Felspar	8%	Chlorite	1%
Calcite and Dolomite	25%	Montmorillonite	5%
Illite	3%	Hematite	2%
Hornblende	1%	Other minerals	6%
Chalcedony	1%		

The photography of the mechanical structure shows quartz grains and heavy minerals weakly cemented together by calcite, dolomite and montmorillonite. A number of grains are coated by illite.

PRACTICAL SIGNIFICANCE OF THE ORIGIN OF LOESS

The distinction between the aeolian loess and the reworked loess has been already felt by the engineer when he calls the former "a silt of very low plasticity" and the latter "a clay of moderate or high plasticity". A most important engineering property of the loess is consolidation, i.e. the decrease of volume when saturated and loaded. When a loess has never been saturated it can consolidate under its own weight when wetted, as it is known for some loesses in the United States where a great number of dams, structures and canals have been built. Where the loess has been waterlaid, consolidation by "prewetting" only will be negligible.

Other properties like swelling, cohesion, etc. probably depend also upon the mode of formation of the loess and this relation is the object of further studies.

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FURTHER DEVELOPMENT OF THE DISSECTION INDEX; A CASE OF A DEPRESSION

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ABSTRACT

The "dissection index" of the Valley of Beth Shean (Israel) is established, by reducing the absolute heights of the effective base of erosion. When the actual Dead Sea Level (–400 m.b. M.S.L.) is used, the median dissection index is 0.13. When the Middle Pleistocene "Lake Jordan" Level is used, the index is twice as high (0.25). The application of this method is suggested in the study of the relation between the relief and the erosion bases in Quaternary.

THE PROBLEM

In our previous paper (Nir 1957) we tried to establish a generally applicable "dissection

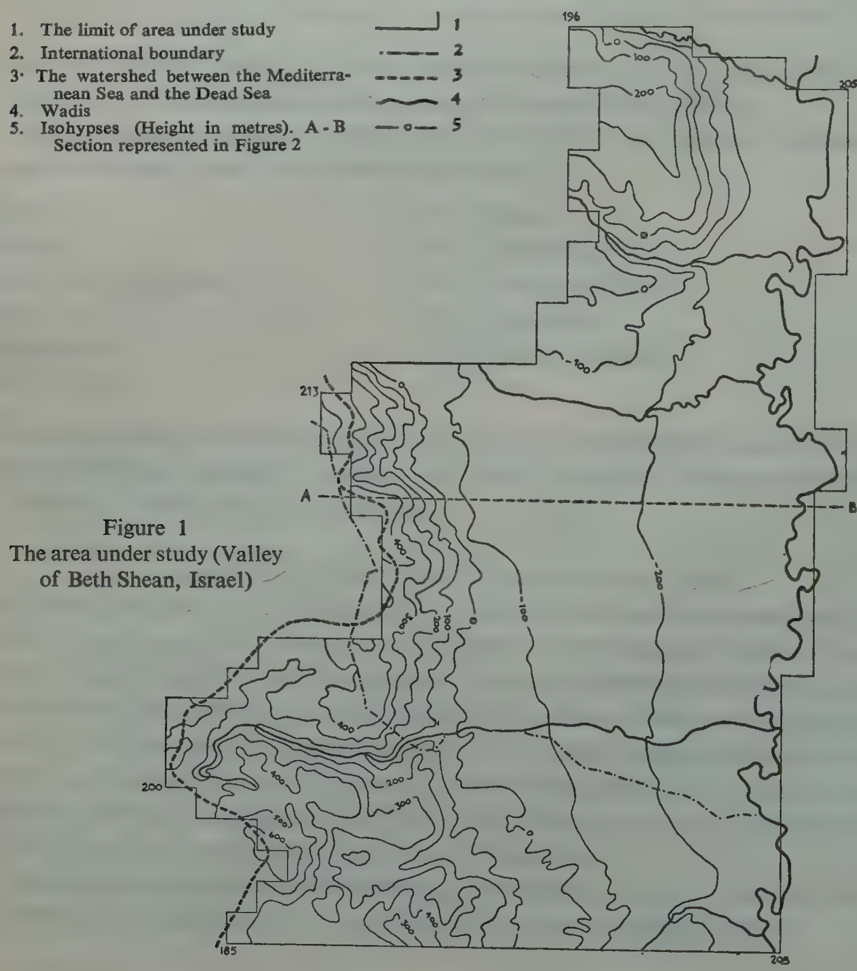

Figure 1
The area under study (Valley of Beth Shean, Israel)

Received September 18, 1959.

index" as a measure of the erosional stage reached by a certain region. This index is the relation between the relative and absolute altitudes of a delimited area (I = rel. alt./abs. alt.). By this, the actual value of the relative altitude is controlled by the absolute altitude. In our present note we shall try to apply this index not to different areas, but to different erosional "régimes", i.e. an application to a region where changes in the altitude of the final base of erosion occurred in the last geological period. This time, our research area occupies the central and widest part of the Jordan Valley — the Valley of Beth Shean (Israel), a depression below the Mediterranian Sea Level (Figure 1).

This region of a total area of 276 square kilometres is divided into two different topographical units: The mountainous area (Mt. Gilboa in the southwestern part, the hills of Lower Galilee in the northwestern part), and the valleys of Beth Shean and Jordan in its eastern part. In the valley of Beth Shean itself, there exist three different topographical levels, clearly distinguished one from another by steep slopes (Figure 2).

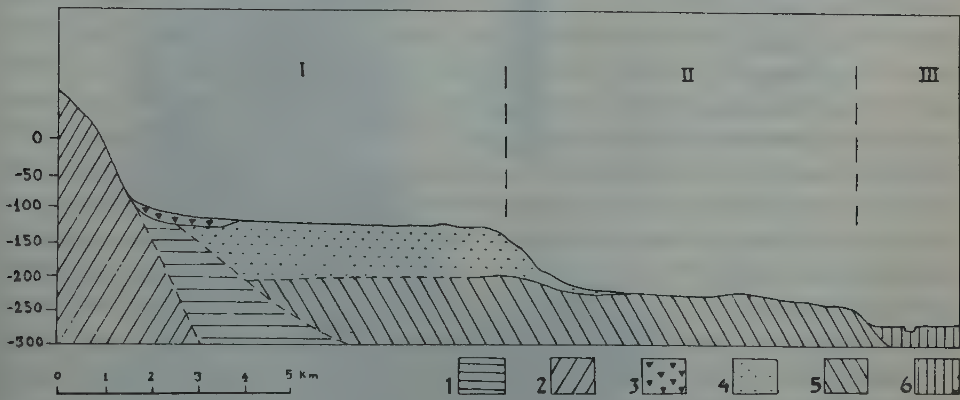

Figure 2

Section trough the valley of Beth Shean (Geology partially after Picard (1929)). 1. Ancient (Lower Pleistocene) alluvial fans. 2. Hard limestone and dolomite. 3. Actual alluvial fans. 4. Calcareous tuff. 5. "Lisan" marl. 6. Recent alluvium. — I, II, III, topographical levels.

The usual topographical map — with the exception, perhaps, of a map on a great scale with a small contour interval — including the whole region under study cannot represent these different levels of the valley, let alone the steep slopes between them. Also, it cannot show the character of the "talweg" of the Jordan, which flows generally between steep cliffs of an altitude of 20–30 m. We tried therefore to express the relief of this area by the dissection index.

A particular problem in establishing the dissection index of this area is its absolute altitude, which is below the M. S. L. In this case, we cannot use the M. S. L. as the erosional base for our index. We adapted the method to this special case of a depression in taking the Dead Sea Level — the actual final erosion base of the region under study — as the base of our calculations: all the absolute altitudes were reduced to this altitude (–400 m b. M.S.L.). Apart from this exception, the index was established

by the method explained in our previous paper. The area was divided into squares of one kilometre each, in which the particular measures were taken.

THE ENERGY OF THE RELIEF

The cartogramme of the relief energy (Figure 3), i.e. the distribution of the relative altitudes in the region, is preferable to the usual topographical map, by demonstrating the division of the region into geomorphological units. It distinguishes clearly between the two principal topographical levels of the valley of Beth Shean, and shows the pronounced relief energy of the transition areas between them. The relative altitude of the two main levels reaches a maximum value of 10 metres on one square kilometer only, but in the transition area it reaches the values of 25–50 m and even

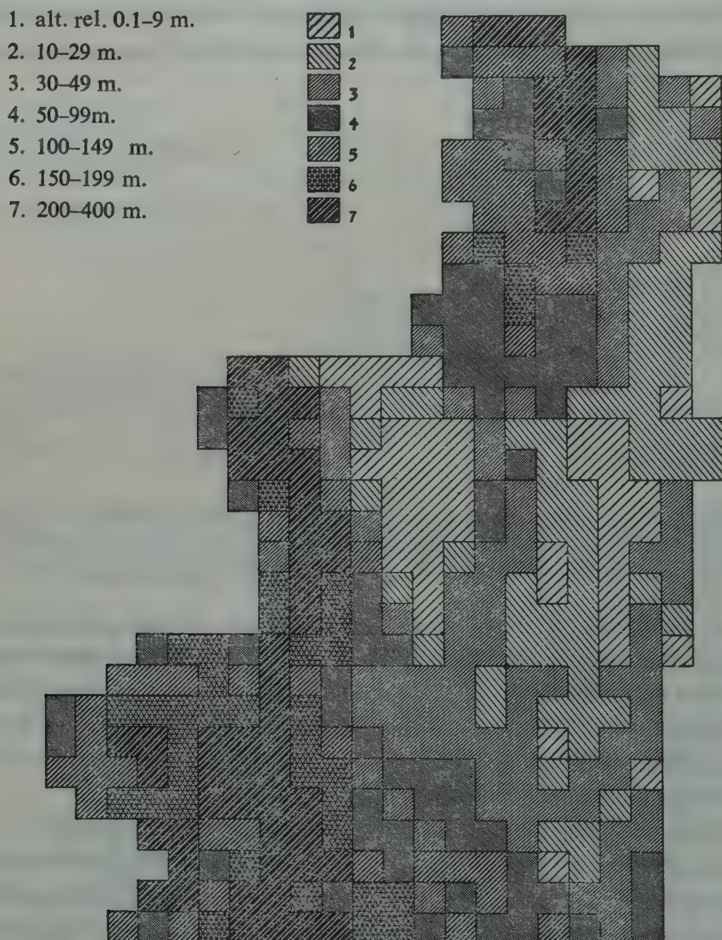

Figure 3
Cartogramme of the energy of the relief.

50–100 m. This phenomenon does not appear on the usual topographic map of the region. The cartogramme also reveals the plateau-like character of the hills of Lower Galilee, in the northwest. In the southern part of the valley, the (relative) roughness of the relief is clearly shown. This is one of the narrowest parts of the whole Jordan Valley, as vast alluvial fans descending from the west close the southern part of the valley of Beth Shean.

The statistical analysis of the relative altitudes gives as the median the value of 50 m; the mode of occurrence of the relative altitudes is 35 m only.

THE DISSECTION INDEX

Our purpose in calculating the dissection index is to study the stage of erosion at which the region arrived. As the Dead Sea Level is to be taken as the actual final base of erosion, we added to each value of absolute altitude in the Dead Sea hydrographical basin the value of + 400 m: I = rel. alt./abs. alt. + 400. Figure 4 shows the distribution of values of this index in the area under study. This cartogramme, as compared with Figure 3, smooths the values of the hills and points out the values of the dissection in the valley, so that the dissection details of the relief are represented with more precision. The smooth dissected plateau-character of the hills of Lower Galilee and of the area of the watershed of Mt. Gilboa is more pronounced; the high degree of dissection of the eastern slopes of these hills is clearly shown (index values 0.50–0.69). The two main topographical levels of the valleys are shown as plains with almost no dissection, which is actually the character of these areas; on the other hand, the steep cliffs of western bank of the River Jordan in this part of its "talweg" are accordingly presented (index values till 0.30). The wave-like surface of the southern part of the valley (small dissection values among medium dissection values), which characterises an alluvial fan relief, is more clearly expressed than in the previous cartogramme.

What stage of dissection has the area reached? The median index of dissection of the region is 0.13, i.e. a very early degree of its erosional evolution; 98 % of the whole area had not yet reached values greater than 0.50, and 90 % reached the value of 0.30 only. We cannot expect high values of the dissection index, as the geomorphological evolution of this area is very young, dating its origins to the Pliocene–Pleistocene transition (Picard 1943). This value is about a quarter of the value of Mt. Carmel (0.50), which is a medium dissected mountainous area. But the value of the dissection index of the valley of Beth Shean, and therefore its erosional stage, has to be further analysed.

The actual topography, with the theoretical final base of erosion of the Dead Sea, is only a very recent stage in the natural history of the landscape. One of the most important former stages in the geological history of this area is the period of the "Lake Jordan", an intermountain lake which extended from Tiberias in the north to Hatzeva in the south in the Middle Pelistocene (Picard 1943). The level of that lake was two hundred meters above the actual Dead Sea level, and reached the absolute altitude of –200 m. This lake was an active base of erosion of the area of Mt. Gilboa

and the eastern flanks of the Lower Galilee; its influence on the evolution of the relief was, therefore, a decisive one. On the other hand, all the areas the absolute altitudes of which are now below –200 m, are posterior to Lake Jordan.

When comparing the actual dissection index — calculated with the Dead Sea Level erosional base — with the dissection index having Lake Jordan as its erosional base,

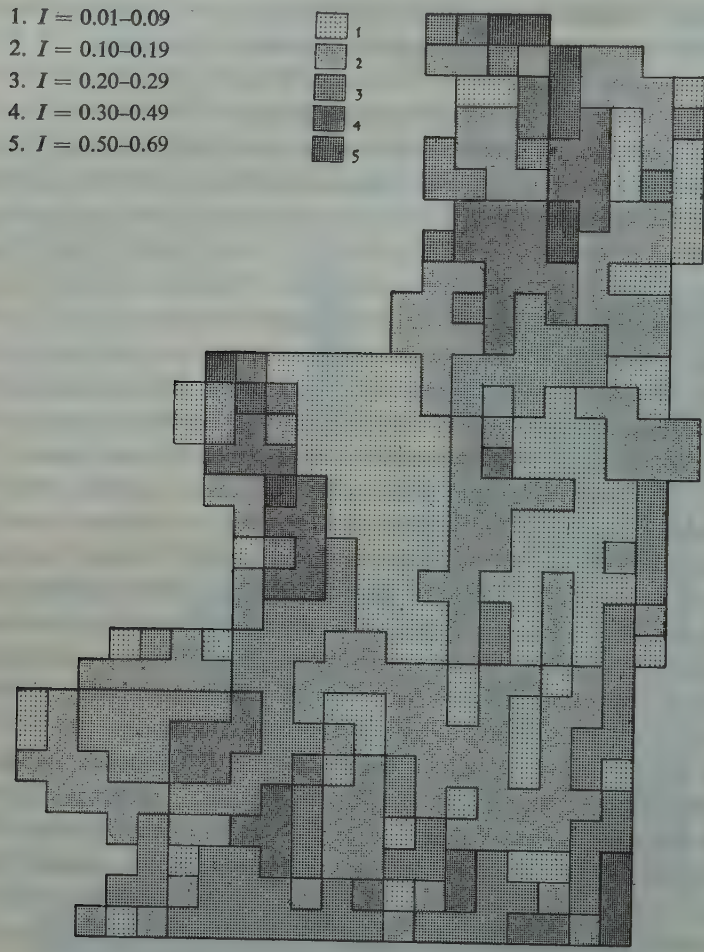

Figure 4
Cartogramme of the dissection index.

we receive the correction of the actual dissection index, computed to its former erosional base. A comparison of the cumulative curves of all the values of dissection indices in the area under study, computed to these two different erosional bases, was carried out on Figure 5. When the actual dissection is related to the erosional base of the former Lake Jordan — a relation which is legitimate, as the actual landscape is,

grosso modo, a landscape inherited from the Pleistocene — we obtain a dissection index of 0.25, twice as high as the actual one.

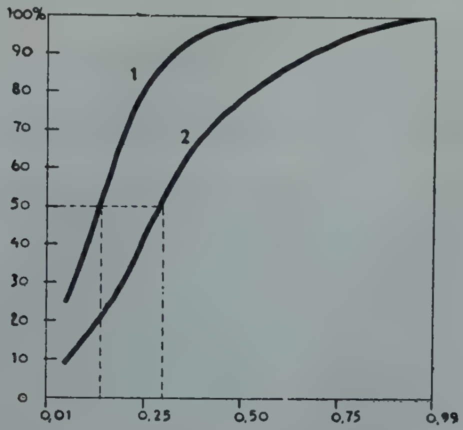

Figure 5
Comparison between dissection indexes of the area.
1. I = rel. alt./abs. alt. + 400
2. I = rel. alt./abs. alt. + 200

APPLICATION OF THE METHOD

The dissection index, when related to various bases of erosion, could reconstruct the reliefs of the particular periods to which the erosional bases are attributed. This index, we assume, can be applied when studying the relation between relief and the regressions and transgressions of the sea level in the Quaternary. The gradient of slopes to their respective erosional bases, or the gradient of the ancient rivers with regard to the former erosional bases can be traced.

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LETTER TO THE EDITOR

An overturned fold on the SE flank of the Makhtesh-Hagadol anticline, N. Schulman, Y. Karcz, and R. Freund, *Department of Geology, The Hebrew University of Jerusalem.*

The following note is the result of observations made in the Makhtesh-Hagadol (Hathira or Kurnub) anticline in the northern Negev, during the instruction of students of the Hebrew University in field-work.

The Makhtesh-Hagadol erosion-cirque is one of the well-known asymmetrical anticlines in the Negev (southern Israel), with a gentle NW limb and a steeply inclined SE limb. The stratigraphy and structure of this anticline were described by various authors[1, 2, 4–6].

The present note deals with a part of the SE limb where overfolding was observed. Bentor and Vroman[2] assumed that the maximum dip attained by the SE limb of the Makhtesh-Hagadol anticline was 95° at the outlet of Wadi Hathira (1532/0398). Closer study has revealed, however, that along a strip running for 3 km from this point in a NE direction, the flank of the anticline is strongly overturned—up to 144°. A detailed structural traverse was performed across the flank, from the Lower Cretaceous beds exposed inside the erosion-cirque of the anticline to the Campanian flint and phosphate at its outer rim. The results were plotted on a detailed 10,000 scale map, from which a section (Figure 1) was geometrically constructed by use of the tangential-arcs method[3].

Figure 2
The hinge of the overturned fold on the SE flank of the Makhtesh-Hagadol anticline, as seen from the NE.

The result of this survey points to the existence of an overturned fold with its axis parallel to the main structure, on which it seems to be superimposed. It plunges both SW and NE, and finally disap-

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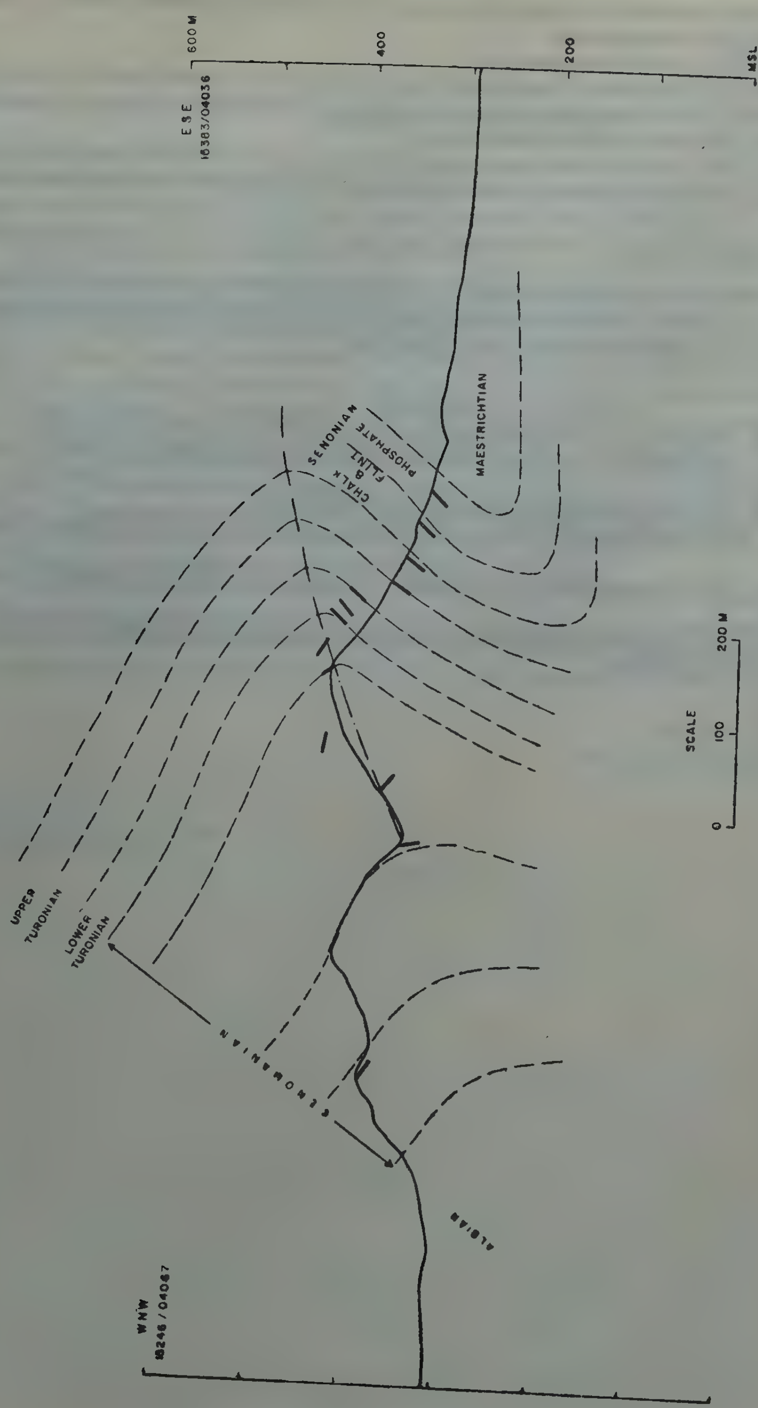

Figure 1
Structural section across the overturned fold on the eastern flank of the Makhtesh-Hagadol anticline.

pears. At one point (1530/0405) the hinge of the overturned anticline is exposed (Figure 2), whereas the synclinal hinge is nowhere seen.

No important faults have been observed.

The fold is built of Cenomanian, Turonian and Senonian rocks only, consisting of hard dolomites, limestones and flints, alternating with softer marls and chalks. A characteristic feature is the attenuation of the softer marly beds in the overturned limb.

It is significant that the above-described overturned fold seems to be shifted a few km to the NE from the apparent structural high of the main anticline, as inferred from the Jurassic rocks in its eroded core.

The dynamic interpretation of the overturned fold is not attempted here as more structural data are required.

A morphological feature directly controlled by the overturned fold is the absence along the 3 km long strip of the impressive Turonian–Senonian hogbacks. Here the overturned strata, dip into the spurs and gullies and form upstream-pointing V–outcrops.

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BOOK REVIEW

DETERMINATION MICROSCOPIQUE DES MINERAUX DES SABLES, by SOLANGE DUPLAIX, Librairie Polytechnique Ch. Béranger, Paris et Liège, 2nd Edition, 1958, 96 pp.

This little book has been prepared for use as a manual in the identification of detrital minerals by microscopic methods. It is introduced by a short description of the methods of preparation of samples and mentions a few points pertaining to the microscopic examination itself.

The main descriptive part discusses 59 minerals arranged in alphabetical order. This includes all those commonly occurring in sediments, in addition to some others which are rare or only of local importance. Opaque minerals are not included. For each mineral the main physical and optical properties are listed. The quality of this information varies considerably. In many instances it would have been more helpful to have ranges of the properties, as commonly found, rather than the very precise data quoted, which may be correct only for certain particular specimens. One is also surprised to find the chemical formula of tremolite listed as $CaMg_3Si_4O_{12}$ or that of muscovite as (H, K) $AlSiO_4$. Other inaccuracies have also crept in. The description includes a useful statement of the most characteristic diagnostic properties, occurrence and likely source rock; 26 of the listed minerals are illustrated by drawings, showing form and general appearance.

Tables of density, relief and birefringence are provided at the end. For identification purposes most valuable will be found the determinative key based on colour, relief, optic sign and birefringence. There is an inadequate bibliography, which does not even mention the standard book on the subject by Krumbein and Pettijohn (Manual of Sedimentary Petrography, New York, 1938).

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Received October 25, 1959

PROCEEDINGS OF THE ISRAEL SOCIETY OF SOIL SCIENCE
AT THE THIRD CONVENTION OF SCIENTIFIC SOCIETIES OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN ISRAEL
Held in Haifa, October 19—21, 1959

The Israel Society of Soil Science was founded in 1950 for the purpose of advancing the knowledge of soils in Israel. It conducts conferences, symposia, lectures, field trips and publishes scientific papers. The Society is affiliated to the International Society of Soil Science.

During the past year, the Society, in cooperation with the Faculty of Agriculture of the Hebrew University, conducted a symposium on the classification and survey of Israel soils. Participants included scientific workers and practical farmers. The symposium was followed by a comprehensive pedological field trip in the Coastal Plain and the Judean Hills in order to familiarize the participants with the principal soil types in these regions.

Of the 70 members of the Society, 46 are engaged in soil chemistry, soil physics and soil microbiology research, soil survey and classification, fertility, irrigation, salinity, soil improvement and reclamation. Most of the research projects are devoted to the study of plant – water – soil relations.

These diverse studies are carried out at the Agricultural Research Station of the Ministry of Agriculture, the Faculty of Agriculture of the Hebrew University, the Technion–Israel Institute of Technology, and various Government institutions.

The Society Executive consists of the following five members: Prof. S. Ravikovitch (Chairman), Eng. E. Muravsky (Secretary), Dr. J. Hagin (Treasurer), Mr. J. Noy and Mr. D. Carmeli.

Headquarters of the Society are at the Agricultural Research Station, Rehovoth.

PROCEEDINGS OF THE ISRAEL SOCIETY OF SOIL SCIENCE

First Session, Monday afternoon 19.10.59
(*Joint session with the Botanical Society of Israel*)
Plant-water-soil relations

Second Session, Tuesday morning 20.10.59 Chairman: S. Ravikovitch

Determination of availability of soil selenium to plants

N. E. Nissim, *Institute of Soils and Water, Agricultural Research Station, Rehovoth*

The data obtained from field survey [1,3] confirm the fact that plants growing in the same seleniferous soils differ in their ability to absorb this element (indicators, accumulators and poorly seleniferous plants)[2]. On the other hand, comparison of the Se contents of plants obtained from different seleniferous areas shows significant differences in the Se accumulating power of each species. Calculation of their Index of Accumulating Power[4]

$$= \text{Total Se content of plant} / \text{Soil Se supplying power}$$

fails to produce constant values.

To clarify the problem of soil Se supplying power (availability), pot tests were made. Common alfalfa (*Medicago sativa*) was grown under similar conditions in 7 seleniferous soils ranging from 0.2 to 2.4 p.p.m. At about blooming time, their Se contents were determined (in the whole plants), and the results correlated as a variable with the soil Se contents, as obtained by the following extraction methods: 1. Distilled water. 2. Bray No. 1 solution. 3. Neutral normal ammonium acetate solution. 4. CO_2–saturated water. 5. Electro-decantation. The curves thus obtained seem to justify the consideration of the electrodecantation extract, in comparison with the other extracts, as the nearest representation of available soil selenium. The apparatus required to obtain this extract was especially designed by introducing basic changes in the Basu electrodialytic cell. This soil extract is supposed to combine (1) aqueous extract, (2) extract of the fraction of soil colloids, such as humus, complex humates, proteins, etc. which behave as negative particles and can pass through the membrane under the conditions of the experiment. This fraction is not present in the other extracts. Its addition is the principal feature of this new method.

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Studies on the mineralogy of Israel soils

M. BEN-YAIR, *The Standards Institution of Israel, Tel Aviv*

The occurrence of minerals in different soil types is described. The question discussed will be whether it is possible to determine a definite mineral or a group of minerals as characteristic of a definite soil type. Some experimental classifications of the characteristic minerals of soil types will be mentioned. From the results of the abovementioned study the following conclusions are arrived at: In well drained, rainy areas, the dominant clay mineral in "Terra Rossa" is kaolin. In poorly drained areas and areas with low rainfall, the dominant clay mineral in terra-rossa is montmorillonite. In rainy areas of dolomitic limestones, terra rossa soil is formed which is rich in montmorillonite, while in brown red sandy soils kaolin is dominant. In other soils, montmorillonite is dominant with varying amounts of illite, kaolin, calcite, etc. It is not possible to establish the identification of soil types on minerals which are of universal occurrence (e.g. montmorillonite or illite), but it is necessary to look for minerals specific to one soil type only. For instance: in rendzina soils there are considerable quantities of calcite and attapulgite passed to the soil from the parent rock. In terra rossa, in addition to the silicate clay minerals, the presence of iron oxides is characteristic.

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Mountain Rendzinas in Israel

S. RAVIKOVITCH AND F. PINES, *Faculty of Agriculture, The Hebrew University and Agricultural Research Station, Rehovoth*

Rendzina soils are found in various climatic regions of Israel; they are formed under humid and subhumid climatic conditions, are prevalent in semi-arid regions and occur in deserts. The soils developed mainly from chalk and marl. These soft parent rocks, especially the marls, differ in their physical properties, chemical composition, and with regard to the quality and quantity of the non-carbonate residue.

The differences in the properties of the rocks have influenced the process of soil formation; consequently, a series of soils was formed varying in morphological, physical and chemical properties, while most of them contain substantial amounts of lime.

In the parent rocks of the rendzinas investigated by us, namely chalk, chalky

marl and marl, differences were found in the amounts of silica and sesquioxides (5–34%); in the ratio of $SiO_2:R_2O_3$ and particularly in the $SiO_2:Al_2O_3$ ratio; in the lime content and amounts of combined water. Potassium and phosphorus vary considerably in their amounts.

The properties of the rocks influenced the supply of clay and its composition in the forming soils, the rate of loss of calcium carbonate, and the development of plants in the soil material formed. In addition, they influenced the development and depth of the soil profile and the texture, structure and colour of the soils. The slow process of decalcification characteristic of many rendzinas has limited the formation and movement of colloids and hence the development of horizons in the soil profile. Accumulation of humus occurs in most of the rendzinas, including those having a high percentage of lime.

Investigation of varieties of soils belonging to the rendzina type has shown large variations in their properties. They differ in depth; lime content (5–80%); silica–alumina–iron compounds content; organic matter content (1.5–8%); in the characteristics of the profile (which is mostly an AC profile); in the texture, structure and nature of aggregation. They differ also in the amounts of plant nutrients, in the composition of exchangeable cations and in colour (having a great variety of colours — white-grey, yellow, brown and black in different shades). The rendzinas differ in their level of fertility and in their suitability for agricultural use.

Clay minerals in mediterranean limestone soils

M. Gitliz, *Faculty of Agriculture, The Hebrew University, Rehovoth**

Quantitative chemical and mineralogical analyses were made on 21 terra rossas, 15 rendzinas and their limestone parent materials from four mediterranean countries, to determine the extent and the cause of their similarities and differences. The mineralogical composition – of the clay fraction between the two groups as well as within the group – was found to be very similar and to reflect the mineralogical composition of the noncarbonate fraction of the parent material — more so in the rendzina then in the terra rossa soils. In the rendzinas no change occurs in any of the clay minerals during their transition from the rock parent material to the soil.

In the terra rossas, however, some changes do occur: the kaolin minerals become enriched, whereas the mica minerals, and to a smaller extent the montmorin minerals, become impoverished. The cause for these differences appears to lie in the "preserving" action of the calcium carbonate, which is present in much larger amounts in the clay fractions of the rendzinas than of the terra rossas.

The colour differences which separate the terra rossas from the rendzinas result from the amounts of free iron oxide present in the clay fraction. The terra rossas,

* Work done at the University of California, Berkeley, Calif.

with red as the predominating colour, contain several times as much free iron oxide as the rendzinas, with gray as the predominating colour. This difference in free iron oxide was found to be inherited from the parent material.

The differences among the parent materials in iron oxide content appear clearly only if the acid-soluble iron oxide is related to the acid–insoluble residue. The ratio which results is larger in the terra rossas than in the rendzinas of each country studied. The present study confirms again the conclusion that the most important process involved in the formation of soils from limestones is the loss through solution of the calcium carbonate of the rocks and the accumulation of the noncarbonate residue. Very little change occurs in the residue as long as calcium carbonate is present within the soil. However, small changes do occur when the calcium carbonate content in the clay fraction is reduced to less than one or two per cent.

Mapping units for generalized soil maps of Israel

J. Dan, *Institute of Soils and Water, Agricultural Research Station, Rehovoth*

The nature of soil mapping units depends upon the scale of soil maps in which they occur. Thus, in detailed soil maps one indicates soil types or even soil phases. On the other hand, in reconnaissance soil maps, as well as in maps whose scales are 1:50,000 or smaller (but usually larger than 1:1,000,000), the primary soil unit is soil association.

Soil association unites within itself several soil taxonomic groups, which usually appear together in the same type of landscape. Its name usually includes designations of two or three of the most impotrant of its soil types or series. Finally, there are schematic soil maps whose scales are 1:1,000,000 or smaller, the soil mapping units usually corresponding to broad geographic and climatic regions.

In Israel, Great soil groups were named some time ago, and the main soil types were also defined, though much more recently. There still exists a need for defining scil assooiations. These units will be especially useful in connection with preparing a generalized soil map of Israel. Work of designating soil associations of Israel is now being carried out at the Agricultural Research Station. As an example of this work, two typical soil associations met in the southern Negev will be discussed.

(1) Calcareous, steppe–desert lithosol–bare hills–aeolian and fluviable loess association.

This association is typical of most of the Negev Highlands. Large highland areas of this region are almost completely bare. However, on the less steep slopes one finds a shallow calcareous soil. In the same region, between the hills, there occur strips of loess soil, and sometimes also of coarse alluvium. While the loess soil strips occupy only about five percent of the total area of this association, their practical importance is considerable.

(2) Hammada–coarse alluvium association.

This association is typical of broad plains of the Southern Negev and of Sinai. It consists of bare areas of hammada soils crisscrossed by wide washes of coarse alluvium, the latter accounting for a large portion of the total area.

The activity of calcium carbonate in the soil as a function of its particle size

J. NOY, *Irrigation Extension Centre, Water Authority*

Some soil types in Israel that have been formed from limestone contain a high percentage of calcium carbonate. Plants growing in such soils sometimes become chlorotic due to the activity of calcium carbonate which disturbs the proper balance of mineral nutrition to the plant. This activity can be expressed as the hydrolysis:

$$CaCo_3 + H_2O \rightarrow Ca^{++} + HCO_3^- + OH^- .$$

Many tests show that there is no correlation between the percentage of total calcium carbonate and chlorosis in plants. Some experiments indicate a possibility that the activity of calcium carbonate is greater as the size of its particles is smaller, because a larger surface area is exposed to the soil solution.

In this work the activity of calcium carbonate was measured for different fractions of particle size, by the reaction with organic acids of different concentrations. Three strongly calcareous soils and three organic acids (acetic, citric and tartaric) were chosen. It was found that the activity of calcium carbonate is very slight in the fraction of particles larger than 200 microns in diameter, the activity is significantly strong in the fraction of size smaller than 20 microns.

It is suggested to assign the term "active limestone" to the fraction of size smaller than 50 microns. A method is presented for the analysis of soil for "active limestone".

No correlation has been found between "active limestone-Drouineau" and "active limestone-Noy" for a number of calcareous soils. No tests have been carried out to find a connection between "active limestone-Noy" in the soil and the appearance of chlorosis in the plant.

Third Session, Tuesday afternoon 20.10.59 Chairman: J. HAGIN

Experiments with mixed fertilizers differing in the solubility of their phosphate contents

J. HAGIN AND J. BERKOVITZ, *Faculty of Agriculture, The Hebrew University and the Agricultural Research Station, Rehovoth*

Three types of mixed fertilizers were investigated, differing in the percentages of their components, and also in the solubility of their phosphorus contents. In addition, the effectiveness of phosphatic rock as fertilizer was investigated. For experimental purposes, superphosphate was introduced, too, serving as standard fertilizer. Both field and pot experiments were conducted.

The field experiments were conducted at Gath (Southern Shefelah) and at Gvuloth (Negev). The fertilizer was applied so as to represent three different levels of phosphorus, the respective quantities being two, four, and six kg of P_2O_5 per dunam. In addition, phosphatic rock was applied containing three times as much P_2O_5 as the other fertilizers, and a control experiment was undertaken without any phosphorus fertilizer.

All plots received equal portions of potash and nitrogen, in each case 6 kg N and 6 kg K_2O per dunam.

An analysis of the Gath field experiments shows that the differences between the five fertilizers were highly significant, and that the same applied to the influence exerted by different quantities of phosphorus.

It seems that the effectiveness of fertilizers on the field referred to above decreased in accordance with the degree of phosphorus solubility. In the Gvuloth series of experiments, the differences are clearly marked between superphosphate, and phosphatic rock, while the differences between the other fertilizers are uncertain. The pot experiments with barley (first growth) conducted at Gath and at Gvuloth show that in general, the fertilizers containing phosphorus in a highly soluble form are more effective than those with a low P solubility. In no instance did the application of phosphatic rock result in an increase in yield.

On Gan Shmuel soil, the influence of phosphorus fertilizers was generally low, and with respect to this soil, it was usually difficult to reach a conclusion. The conclusions concerning pot grown maize (second growth) resembled those arrived at in the instance of first growth.

Nitrification experiments for the determination of available nitrogen

J. Halevy and J. Hagin, *Agricultural Research Station and Faculty of Agriculture, The Hebrew University, Rehovoth*

Though the availability of nitrogen for plants is often correlated with the amount of total nitrogen in the soil, it has long been recognized that the total nitrogen is of little value as an expression of the available nitrogen to crops. The mineral nitrogen content of the soil, being subject to many changes, cannot be used to determine the need for nitrogen fertilization.

Many investigators therefore[2,3,4] tried to correlate the rate of mineralization of organic substances in the soil with the availability of soil nitrogen to plants.

Hagin, Ravikovitch and Halevy[1] found a correlation between the response of irrigated corn crop to nitrogen fertilization and a certain incubation technique. In the present work we tried to shorten the incubation time. It was shown that more nitrate was formed during incubation at 37 °C for one week than for 2 weeks at 30 °C. This has also resulted in better agreement among the replicates.

No desirable results have been obtained by further incubation experiments, either without previous leaching or by percolation methods.

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Comparison of Negev raw phosphate material (Cyclone) with ordinary superphosphate as fertilizer

L. Carmel (Vinick), *Institute of Soils and Water, Agricultural Research Station, Rehovoth*

Previous investigations have shown that in soils with *p*H values below 7.0 the solubility of "Cyclone" is adequate to make the material a possible substitute for superphosphate. An attempt was made to evaluate the equivalent amounts needed in practice.

Comparisons were made with two soils: Terra rossa of *p*H 6.5 and Brown-Red Sandy soil of *p*H 6.6. Alfalfa plants were grown in pots.

The results showed that yields obtained with addition of two, three and four increments of P_2O_5 in the cyclone form were similar to those obtained with single increment of P_2O_5 in superphosphate form.

Differences, however, were not significant statistically.

Additional field experiments will be initiated.

Production of mixed fertilizers from Huleh Peat and testing their efficiency in the field and in the laboratory

K. M. Schallinger, *Institute of Soils and Water, The Agricultural Research Station, Rehovoth*

After preliminary experiments with processed peat in the greenhouse where its efficiency as a fertilizer was proved to be equal to that of ammonium sulphate and that of blood meal, field trials were carried out.

For that purpose larger quantities of the ammoniated peat had to be prepared in a specially erected pilot plant. To the nitrogen enriched peat, phosphate was added, to act both as a plant nutrient and as a nitrogen stabilizer. To make the peat fertilizer complete, potassium was also added.

Three crops were grown in rotation. Higher yields were obtained from plots fertilized with the beneficiated peat.

The decomposition of the organic matter and the nitrification rate of the product were studied and compared to manure and ammonium sulphate.

Application of a method for measuring short–term phosphate absorption by plants

U. KAFKAFI AND J. HAGIN, *Agricultural Research Station and Faculty of Agriculture, The Hebrew University, Rehovoth*

Stanford[2] suggests an approximately 1–week method for measuring nutrient absorption by plants[3]. His method is more economical than Noibauer's[1] and is more suited for routine laboratory work with soils.

The method was tried here on artificial soil systems. The results are discussed here with the application of the method.

The availabilities are compared of two kinds of fertilizers: (1) monocalcium phosphate, and (2) dicalcium phosphate. The "soil" system was prepared from acid-washed sand, acid kaolinite and calcium carbonate mixed together in various ratios.

The fertilizers were in contact with the "soil" for periods ranging from 0 days to 3 months, before they were transferred to the plants.

It was found that the calcium carbonate caused a very sharp decline in the availability of phosphates to plants.

After 2 weeks of contact between the fertilizers and the "soil", there was no difference in absoption of phosphate from the two fertilizers. In both cases the absorption was found to be equal to zero.

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Utilization of sewage water to irrigate crops on shifting sands

E. MURAVSKY AND B. ROMATI, *Agricultural Research Station, Rehovoth*

Field trials on the utilization of urban sewage water to irrigate field crops were conducted at the Holon Experimental Farm. From the preliminary results it is possible to conclude the following:

1. Sand treated with this water became quite stable, and after only one growing season was transformed into a medium sufficiently fertile for crop growth. This was especially true regarding alfalfa and pasture plants.

2. There was a significant increase of organic matter in the upper layer of sand.

3. With continued irrigation there was no observed accumulation of soluble salts in the sand.

4. It appears that for sands irrigated with sewage water there is no need for the addition of animal manure. However, crops responded favorably to the addition of phosphorus fertilizer.

5. A variety of forage crops developed well, and their yields were no less than those obtained on fertile soil.

Lowering of the *p*H in calcareous soils

A. PORATH AND SALAH FEIGENBAUM, *Institute of Soils and Water, Agricultural Research Station, Rehovoth*

Lowering of the *p*H in calcareous soils is often desirable for such plants as ornamental flowers, bulbs and onions, in order to control certain parasitic diseases and to improve iron and manganese uptake. Experiments were carried out on soils containing from 12 to 65% lime. Addition of sulphur resulted in an appreciable drop of *p*H values from 8.2 to 7.5. The trials were held both in the laboratory and in the field.

Salt tolerance of cotton in various soils

B. ROMATI AND S. RAVIKOVICH, *Agricultural Research Station and Faculty of Agriculture, The Hebrew University, Rehovoth*

A pot experiment to grow cotton in three different types of soil brought up to four salinity levels was carried out.

Soils used:

a) Alluvial clay soil from the Valley of Yizreel.

b) Calcareous soil from the Bet Shean Valley.

c) A loess soil from the Northern Negev.

Salinity levels:

Soils with 0.10–0.15% soluble salts (controls).

Soils with the addition of NaCl up 0.25%, 0.40%, 0.60% of soluble salts.

In the control soils the development of the plants and yields obtained were about the same in the alluvial and calcareous soils; in the loess soils the yields were lower. In the different soils the addition of salt affected the plants to various degrees. No significant differences in weight – of bolls and seeds per pot obtained from the control alluvial soil, and that obtained from the salinized alluvial soil were – observed. However, in the calcareous and loess soils, differences between controls and salinized soils beginning with 0.40% salinity level were quite significant.

Examination of salt concentrations in the extracts of the different soils from their saturated pastes and their relation to yields obtained have shown that frequently, at close salt concentrations, the yields were different. The highest yields were obtained from alluvial soils.

The effect of salt additions on the soils and plants, such as the penetration of the exchangable Na into the soil complex, the change in the percentage of stable aggregates, and ash and chloride contents of the plant leaves, were also investigated.

Fourth Session, Wednesday morning 21.10.59 Chairman: J. RUBIN

The influence of rainfall intensity on the moisture profile during infiltration into a disturbed soil

R. STEINHARDT AND J. RUBIN, *Institute of Soils and Water, Agricultural Reaserch Station, Rehovoth*

The influence of rainfall intensity and duration on moisture profile in soil columns was investigated.

Rainfall intensity affected the moisture profile very significantly. The effect (in the moisture range investigated) can be expressed by the approximate relation:

$$Pw = \alpha\, I^{\beta}$$

where Pw = Percentage moisture on dry weight basis, I = Rainfall intensity (mm/hour), and α, β = constants.

An attempt is made to explain this effect on the basis of soil properties: conductivity, diffusivity and moisture–tension characteristics.

As a summary and basis for further investigation, hypotheses are presented, concerning the direct and indirect influence of the wetting process on soil and vegetation, principally in connection with prevailing irrigation practices.

Rainfall absorption capacity of soils

J. RUBIN AND R. STEINHARDT, *Institute of Soils and Water, Agricultural Research Station, Rehovoth*

The capacity of soil to absorb rainfall of a given intensity may be gauged by the maximum amount of water which can infiltrate into the soil under given conditions before ponding occurs. Such a quantity is of basic importance in connection with many soil erosion and sprinkler irrigation problems.

Experiments designed to show dependence of rainfall absorption capacity upon certain soil and rainfall characteristics will be described. Certain aspects of the theory of the processes involved will be developed. In particular, the applicability of the equation characteristic for diffusion phenomena modified by an external force field will be examined. Finally, the use of the above considerations in connection with the problem of adjusting the water application intensity of irrigation sprinklers to soil infiltration characteristics will be discussed.

The feasibility of mole drainage for certain soils

J. SHALHEVET, *Agricultural Research Station, Rehovoth*

The practice of draining soils by means of mole drains has been known for many years. However, because of its limitations, the method is not used very extensively.

The method is suitable only for certain soils under specific conditions of climate and crop, and the purpose of this work was to determine the feasibility of its use under certain soil conditions.

The experiment consisted of three variables: (1) two levels of artificial drainage, (2) three levels of natural drainage, and (3) two varieties of alfalfa. The response to treatment was determined by stand count, plant height and final yield. A continuous record of drain discharge was obtained, and this was compared with rainfall intensity. In this way the performance of the drains could be analysed. The durability of the drains was also measured.

Design of furrow and border-check irrigation systems and comparison with sprinkler irrigation

E. Rawitz, J. Rubin, Y. Krupnick and G. Loewenstein, *Agricultural Research Station, Rehovoth*

The success of an irrigation method may be judged by the efficiency of water use, soil and crop response, and costs. With the introduction of large-scale cultivation of industrial row crops, furrow irrigation has assumed considerable importance for Israel agriculture. Labour costs of sprinkling tall-growing field crops are excessive, and there is reason to believe that considerable water losses occur under these conditions as well. In other cases, the occurrence of plant disease may be a function of the irrigation method.

Primary and supplementary field experiments were conducted in several parts of the country, and information was obtained regarding the uniformity of water distribution for various slope-head combinations, maximum length of run, water application efficiency, yields, and labour efficiency. It was found that under certain conditions furrow irrigation is preferable to sprinkling.

Continuation of the comparison of border-check flooding and sprinkling of alfalfa has confirmed the data presented in 1957 before this Society; there is a tendency for better yields under flooding, and this may be due to better distribution of water, as well as to improved control of prodenia, a common alfalfa pest.

In addition to the above, changes of soil properties with time were investigated, and some advances were made in formulating a theory which would enable the prediction of border-check and furrow system performance for the purposes of design.

Absorption, retention and transpiration of THO by plants from tritiated water

S. Gairon, J. Rubin and A. Cohen, *Agricultural Research Station, Rehovoth*

The roots of two-week old bean plants were placed in contact with tritium-labelled water by transferring the plants in a tritiated nurtient solution, or by irrigating the growth cans with tritiated water.

The concentration of THO, and its variations, in the solution (or the soil water), in water extracted from different plant parts, and in transpired water, has been measured. The results of these experiments will be discussed.

Possible uses of water labelling with tritium in measuring evapotranspiration of phreatophytes will be shown.

Interactions of tillage and soil structure

D. HILLEL AND S. DASBERG, *Agricultural Research Station, Rehovoth*

In a series of field trials the interrelations of soil structure and tillage were investigated. Draft requirements for different implements working in different levels of soil moisture were correlated with mechanical properties of the soil, such as shearing strength and penetrability. The results of tillage actions were evaluated in a series of physical tests. Bulk density, air permeability, aggregation, drying rate and cracking were measured. Auxiliary laboratory investigations yielded additional supporting data, serving to clarify fundamental aspects of the work.

The influence of seedbed compaction on soil structure and on crop response

S. DASBERG AND D. HILLEL, *Agricultural Research Station, Rehovoth*

Different degrees of compaction were carried out prior to, and immediately after, the planting of grain sorghum under dry-land farming. The effect of compaction on bulk density, mechanical strength, air permeability, drying rate and cracking were measured. Correlations between soil properties and plant response were calculated.

It was found that germination and emergence were enhanced by compaction, but subsequent development was thwarted in the extreme treatments. Optimal values for compaction were found, and practical means for their determination were devised.

Preliminary observations on methods of reducing soil temperatures

G. STANHILL, *Agricultural Research Station, Rehovoth*

It has been suggested that the germination and development of some vegetable crops are inhibited during the summer months in Israel because the soil temperatures are too high.

Preliminary observations were made at Gilat, in the northern Negev, during the summer of 1959.

A surface dressing of magnesium carbonate was applied to increase the albedo of the soil and this reduced the soil temperature at 2 cm depth by a maximum of 19 °C. The effect of the treatment lasted unimpaired for 15 days and a small reduction in

soil temperature was still measureable after 35 days. The treatment also reduced evaporation from the soil. Wetting the soil also caused a substantial reduction in the temperature at 2 cm depth. The maximum reduction recorded was 13 °C, and 10 days after watering the temperature was still 5 °C lower than the unwatered control plot.